FERTILISERS AND SOIL IMPROVERS

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DESCRIPTION, APPLICATION, AND COMPARATIVE VALUE

BY

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PREFACE

In recent years much attention has been given to the manufacture and the use of fertilising materials, for the purpose of improving the yield and the quality of the crop.

It is becoming increasingly important that care should be taken that soils be not exhausted of their plant food, especially as so many intensive systems of cropping are in vogue, whereby these plant nutrients rapidly suffer depletion.

As a result of the remarkable expansion of nitrogen-fixation processes, several new and concentrated fertilisers of considerable purity and value are being produced, as well as some which supply all the ingredients considered necessary for plant life. It is not unlikely that, in the near future, these may alter materially the existing schemes for manuring.

An attempt has been made in the following pages to classify and describe briefly the chief fertilisers of commerce, and their value as plant foods; it is hoped, therefore, that this manual may be of assistance to the farmer or gardener in his choice of a fertiliser or manure.

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CHAPTER I

THE SOIL AND SOIL CONDITIONS

Introductory.—The fertility of a soil depends upon its structure, and upon its organic and inorganic constituents. This involves many variable factors: the natural capabilities, weather condition, amount of organic matter, plant diseases, soil reaction, supply of plant food, and the condition brought about by long and correct cultivation.

Its treatment, therefore, is a matter of experience, good judgment, and common sense, rather than the application of definite rules. The productiveness is not entirely dependent upon the food supplies which the land contains, for many soils which give a high proportion of plant food on analysis, do not give the high yields expected, owing to their resistance to the free passage of air and water. Conversely, very light lands often suffer from drought, owing to the fact that they fail to hold adequate supplies of water needed for the crop, although they contain the necessary food in sufficient quantity.

Soils showing the greatest fertility are usually those having a texture which allows free access of air and water,

yet not free enough to allow water to pass straight through them. They generally contain organic matter also.

Mechanical structure is vitally important, and no amount of fertiliser can make any marked improvement upon land which is in bad condition as regards its tilth. The fertility will depend as much upon its physical state as upon the food supply, and when the soil is in good condition it will respond readily to fertilising materials, and give the greater return in value for the money spent on these substances.

The amount and quality of the produce which is obtained from a soil may be bettered in two ways; by the improvement of the land, and by the feeding of the plant. The soil must be brought into suitable condition by cultivation, liming, green manuring, the application of farmyard manure, and efficient drainage, and the plant fed by means of artificial fertilisers.

No plant growth, or rather, no vigorous plant growth, can take place without air, water, and the land in suitable condition, and these facts must be appreciated before there can be any marked results from the application of fertilisers.

Some knowledge of the soil, its constituents, and the best conditions for growth, is necessary for the intelligent employment of food materials for the crop.

The soil.—The composition of the soil may be looked at from the physical, chemical, or biological point of view: physically in regard to its particles, chemically in reference to its food supply and reactivity, and biologically when considering the millions of micro-organisms at work in it.

Soils consist of mineral matter derived from rocks, the calcium carbonate, calcium phosphate, and organic matter obtained from marine and other organisms, the

soil water, and the residues of materials grown on the soils.

In the main soil may be put into three classes, which in their turn may be sub-divided as follows :—

CLAY { Heavy clay, Medium clay, Loamy clay }

LOAM { Clayey loam, Loam, Sandy loam }

SAND { Loamy sand, Sand }

In addition to these classes are marls containing from 5–20 per cent. calcium carbonate, the rest being silt and clay; calcareous soils containing more than 20 per cent. calcium carbonate (chalk), and peaty or humic soils which have more than 20 per cent. humus. Sandy soils contain less than 6 per cent. of clay, loams from 6–15 per cent. clay, and clay land from 15–25 per cent. clay, but sometimes considerably more.

Mechanically the soil is composed of a vast number of particles of various sizes, and it has been found convenient for the purposes of comparison to separate these particles according to their size. This method is a common one, but is quite arbitrary. In England it is usual to divide the particles into groups having the following dimensions.

Stones	above 3 mm. diameter.
Gravel	between 1 and 3 mm. diameter.
Coarse sand ..	,, 0·2 and 1 mm. diameter.
Fine sand ..	,, 0·04 and 0·2 mm. diameter.
Silt..	,, 0·01 and 0·04 mm. diameter.
Fine silt	,, 0·002 and 0·01 mm. diameter.
Clay	less than 0·002 mm. diameter.

It is important to distinguish between the silt and the clay, as fine silt has great water-holding power, and in excessive amounts makes the soil difficult to work. It is worse than clay in this respect, in that lime will alter it but little.

Coarse silt is a valuable ingredient, and an essential constituent of loams, in which it exists to the extent of from 30–40 per cent. It holds water well and does not dry out.

Fine sand is contained in most soils to the extent of from 10–30 per cent. If 40 per cent. is present, there is a danger of drought in hot weather.

Coarse sand, if in suitable amount, keeps the soil open and friable. It should be stated here that the official method for the mechanical analysis adopted by the Agricultural Education Association in 1925 consists in the use of hydrogen peroxide to destroy organic matter and thus aid the complete dispersion of the soil, together with a shorter method for obtaining the percentage of the fractions, depending on the depth-concentration relationship in a settling suspension. Both these improvements, which were introduced by Robinson (*J. Agric. Science*, vol. 12 (1922), pp. 287, 306), have been examined by a sub-committee of experts, and extensive experiments have been carried out at Rothamsted, Leeds, and Bangor.

Details of this work and a detailed discussion of the present position of mechanical analysis can be found in the *Journal of Agricultural Science*, vol. 16 (1926), p. 123.

In the new method the 3 mm. sieve is discarded, and the mechanical analysis made on that part going through the 1 mm. sieve, the fine gravel being included with stones and gravel.

The statement of results by this scheme now includes the following :—

Moisture in air-dry soil.
Loss on ignition, corrected for carbonates present.
Carbonates.
Coarse sand remaining on 100-mesh sieve.
Fine sand, determined by sedimentation.
Silt, Fine silt, Clay — Determined by pipette sampling.
Loss by solution in hydrogen peroxide and hydrochloric acid treatment.
Stones and gravel are reported separately.[1]

Clay soils.—There are two kinds of clay soils; one containing 20 per cent. or more of clay, the other containing considerable quantities of fine silt. The difference between these two types is that the clay in one can be flocculated by lime, or exposure to frost, but that containing the fine silt cannot be flocculated, and soils holding considerable quantities of this material are very unmanageable.

Clay can exist in either a sticky state or in a flocculated, crumbly condition, and it impresses its properties on the soil to a large extent, so that if in the sticky condition, the whole soil will become sticky. Conversely, if the clay is in a crumbly state, the soil will be friable and more open.

The addition of lime, chalk, or limestone causes the change from the sticky to the crumbly state to take place. Organic matter, frost, and good cultivation have the same effect. Liquid manure and sodium nitrate, which leave the soil in an alkaline condition, deflocculates the clay and brings it back to the sticky state.

[1] The method is described in *Agricultural Progress*, vol. 3, 1926.

Fine silt cannot be flocculated or made crumbly by any known means. Clay is an important reservoir of plant foods, notably potash, phosphate, and sulphur, and the manurial treatment for clay soils consists mainly in the application of lime and phosphates.

Dung also improves these soils, and in some cases ammonium sulphate, and grass is the most suitable crop.

Lime and certain sodium salts liberate potash from clay soils.

Close attention must be paid to the drainage of clay land.

A heavy clay soil holds water, bakes badly, impedes the movement of air and water to the roots, evaporation proceeds slowly, and the soil beneath the top layer becomes cold. These conditions prevent, or at least retard, the processes for the preparation of plant food. With much clay in wet weather, it becomes sticky, and cannot be worked, and in dry conditions bakes hard, and shrinks.

For an average rainfall, from 8–16 per cent. clay in soil is sufficient.

Sandy soils.—The chief property of sandy soils is that they are porous, and allow water to pass freely from them. It is quite usual for them to suffer from drought during hot weather. The rapid movement of water also carries with it the soluble plant food.

Admixture of silt improves these soils, in that it retards the rapid filtration of water. A sandy soil is warmer than a clay one. It requires regular additions of organic matter, lime, and fertilisers. Stable manure, if available, is very suitable for a succession of crops, and this manure is often supplied through the medium of live-stock kept on the land. Another method of applying organic matter to

the soil is to plough in a leafy crop. This method is called green manuring, vetches, clover, and mustard being suitable crops for the purpose.

Soluble fertilisers must only be added in small quantities at a time as they are easily washed out and lost.

Sandy soils can be worked at any time, and intelligently managed, and well manured, can be made to yield heavy crops.

Loams.—The soils of this type lie between clay and sand in their properties, and usually contain not more than 10–15 per cent. clay, and not more than 20 per cent. coarse sand. Their value varies according to the proportion of these main ingredients. In light loam sand predominates, and in heavy loam there are larger amounts of clay. The best loams have a light brown colour, are of moderately fine texture, can be crumbled when dry, and are fairly retentive of moisture and of heat. They are usually the most fertile lands in the country, and almost any crop will grow on them.

Soils of this type respond well to farmyard manure, and often cows or bullocks are kept on the land to provide manure. On the lighter soils sheep are sometimes kept.

Loams are very suitable for rotation crops, such as clover, wheat, swedes, and barley, to give a type. Light loams are prone to weeds, but are good for fruit and market gardening. Clover is a useful crop in that it grows well on this soil, and also adds nitrogen by the fixation of this substance from the air, by means of certain bacteria on the nodules of the roots of this plant.

Chalk soils.—Chalk is present in nearly all soils. The proportion varies enormously, and may be as high as 50 per cent., but in a loam is usually below 1 per cent. It is constantly being removed as it is soluble in water containing

carbon dioxide. Chalk soils require special care in cultivation, and should be well worked.

Organic matter is very necessary and leguminous crops such as lucerne and sanfoin are specially valuable. Superphosphate is needed for root crops, and potash for clover. Chalk soils are prone to weeds.

Humic soils.—These soils, of which peat soil is a type, usually contain more than 20 per cent. humus. They are more retentive of moisture than chalk soils.

Soil constituents.—In chemical composition soils vary greatly, especially in regard to the amount of lime present. The following are the figures for average soils :—

Silica	80·00–85·00 per cent.
Alumina	9·00–10·00 ,,
Magnesia	0·20–0·50 ,,
Lime, CaO	0·60 per cent. average.
Sulphate	0·02–0·30 per cent.
Nitrogen	0·10–0·20 ,,
Phosphoric acid	0·05–0·30 ,,
Potash	0·05–2·00 ,,

Silica.—This material, in the form of sand, quartz, and flint, is one of the commonest substances of the earth. In these forms it is very hard, not easily powdered, and very slightly soluble in water. Its resistance to water is its most striking property. It is not a plant food, and gives nothing actually to the plant, but it has important uses in that its large particle size and irregularity allow passage of air and water through the soil.

Silicates.—The clay constituents of the soil are among this class. They are important mineral ingredients of the soil, and exist as the silicates of calcium, aluminium, iron, magnesium, sodium, and potassium. Mainly they are resistant to the action of water, and some react with other substances which are added to the soil.

Calcium.—This material existing as calcium carbonate

or oxide, or other calcium compound, has marked effects upon clay, rendering it less tenacious and plastic. Chalk also acts as a weak base, and in this way is essential to the important process of nitrification.

Calcium phosphate.—An essential plant food. Soils in Britain usually contain from 0·2–0·4 per cent. of tricalcium phosphate. It is readily detected by heating 20 grams of the soil with concentrated hydrochloric acid for an hour, filtering, and adding a solution of ammonium molybdate to the filtrate. A yellow precipitate is produced if phosphate is present.

Potassium.—An essential plant food. In fertile soils it exists to the extent of from 3–4 lb. per ton of soil.

Sodium.—Certain sodium compounds are used in agriculture, such as sodium nitrate and sodium chloride, but in most cases it is the acid radicle which is of value, the nitrate in the sodium nitrate, unless the sodium renders the potash more available, as that in the sodium chloride under certain conditions.

Sulphur.—This substance occurs in plants in the form of sulphides and sulphocyanides of organic bases, and in the nutrition of the plant plays an essential part. It is to be noted that metallic sulphides are poisonous to plants, and that in all probability they obtain all the sulphur they need from sulphates in the soil.

Magnesium.—This substance is always present in plants.

Iron.—An essential constituent of plants, but very small quantities appear to be sufficient.

Aluminium.—According to certain authorities, salts of aluminium benefit wheat, barley, and flax.

Chlorine.—Always present in soils and stated to be an essential constituent.

Fluorine.—Applications of calcium fluoride are said to have beneficial effects upon the soil for some crops.

Nitrogen.—All organisms require nitrogen to build up their tissues, and compounds of nitrogen are essential in the food supply of both plants and animals. The nodules on the root hairs of certain leguminous plants contain nitrogen-fixing bacteria.

Water.—This material is an essential constituent of soils, and exists to the extent of about 9 per cent. in sandy soils, 12 per cent. in loams, and 27 per cent. in clays.

Air.—The air in soils usually contains more carbon dioxide than atmospheric air, being in the neighbourhood of from 0·4–1·5 per cent., as compared with 0·03–0·04 per cent. for atmospheric air. This constituent in the soil is of great importance with reference to vegetable life.

Oxygen.—The oxygen of the air plays an important part in the life of animals and plants, in the processes of respiration, combustion, and decay. The changes in the soil, such as fermentation, and the putrefaction and decay of animal and vegetable matter, are intimately connected with combination with oxygen.

Organic matter.—This occurs in soils from the remains of previous generations of plants, together with more recent undecomposed matter and some partly decomposed material, called humus. The undecomposed part of the organic matter is the source of humus, and keeps the soil open and porous.

Humus.—A black or dark brown substance of vegetable origin. It is a product of the action of bacteria, which attack the carbon compounds of plant tissue, and is mainly formed when air is absent. Its composition is complex and indefinite, and it appears to consist of several substances, of which ulmin, humin, ulmic acid, humic

acid, apocrenic acid, and crenic acid are the more clearly understood, but comparatively little is known of their action on the soil. Humus has great effects upon soils, in improving the texture and regulating the temperature, and soils which have been enriched with humus through the repeated application of farmyard manure will resist drought better than those with a low value in this commodity. In general, soils containing humus are regarded as fertile.

Soil conditions for growth.—The soil conditions affecting plant growth are water supply, air supply, climate, temperature, supply of plant nutrients, and various injurious factors.

Water and air supplies are dependent upon the proper fineness of division of the particles in the soil, porosity, and retention of moisture. These conditions are brought about by the methods of cultivation: ploughing, harrowing, draining, and the addition of farmyard manure and lime in some cases. A soil should be open to admit air and water, but should not be too porous or water will flow too easily, and the plant may suffer from drought. The texture of the soil depends upon the size of the soil particles, and the addition of lime tends to pack these particles into larger aggregates. Basic slag or compound fertilisers containing carbonate of lime also produce this result, but compounds of soda such as sodium nitrate break down these aggregates.

The action of the plant nutrients depends upon the food supplied, its sufficiency, and the conversion of complex materials into simpler bodies, such as the change of complicated nitrogenous materials into nitrates by means of micro-organisms.

Food supply.—The materials necessary for plant life are carbon dioxide, oxygen, water, and suitable compounds

of nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, and iron. Manganese and silicon are also known to be beneficial, and it appears that bromine, fluorine, iodine, chlorine, aluminium, and zinc in suitable traces benefit plant growth. Very small amounts of copper, boron, barium, strontium, and arsenic are also found in plant ash.

All the substances, other than nitrogen, phosphorus, and potassium, are, however, present in the soil, in the air, or brought down in the rain in sufficient amounts to provide these traces.

Nitrogen, phosphorus, and potassium are required in large amounts, and have to be added to the soil by means of fertilising materials. These elements do not exist as such in soils, and are always referred to as nitrogen, phosphoric acid, and potash, these being convenient terms for use in the comparison of analyses of soils, and in the valuation of fertilisers. Actually, nitrogen is in combination, usually as nitrate or nitrite, phosphoric acid as phosphate, and potash as salts of potassium.

Plants synthesise their own food from various substances taken out of the soil, and although we speak of these as actual food, they are only the raw material from which the food is manufactured.

Nitrogen, phosphoric acid, and potash are the most important foods required by the plant, and cultivation and the activities of bacteria render plant food more available for the plant. Organic manure provides suitable material for the bacteria to live on.

In an efficient fertiliser the plant foods must be in suitable condition for immediate assimilation by the plant, or must be capable of speedily assuming this condition after mixing with the soil.

Nitrogen.—Nitrogen in the form of nitrate is the best nitrogenous food for plant life, and the addition to the soil of these salts give marked improvement in growth. Excess of them is bad, however, in that they render the plant liable to attack by insect and fungoid pests, and also retard ripening. Cereal crops produce too much straw if nitrate is in excess, and root crops too much leaf. Plants grown for the sake of their leaves are generally improved by an increased nitrate supply.

Organic matter.—The whole chain of processes of changing organic matter is very important to soil fertility, because the undecomposed residues are converted into the valuable humus and plant food.

Organic matter has no direct fertilising value, but it derives its importance from the nitrogen, phosphorus, and potassium it contains. Before these elements can be utilised for the plant, decomposition must take place in the soil. This is accomplished by earthworms dragging the material into the soil, when certain moulds and bacteria are the decomposing agents. The fibrous material contains protein, which is broken down into ammonia and other substances, some of which, with the cellulose, give rise to the complex material known as humus, and carbon dioxide is evolved. The fertilising value depends upon the rate of decomposition, which is a measure of its bacterial activity. The ammonia produced is oxidised into nitrates, which are taken up by the plant to build up into protein again. The process of the conversion of organic matter into nitrates is termed nitrification, and the nitrogen in organic matter and humus is converted into nitrates through the stages of ammonia and nitrites by means of different micro-organisms.

Nitrification occurs if suitable food is present, particu-

larly in the presence of phosphates, lime, sulphates, and carbon dioxide, also when basic materials are present to combine with the nitrous and nitric acids produced. A suitable temperature and sufficient moisture are also necessary. The action of the organisms is hindered by the presence of alkali.

A chemical change involving the liberation of free nitrogen from nitrates is called denitrification, and takes place under some conditions in soils and manure heaps. Certain micro-organisms are responsible. Straw contains bacteria which can, in the absence of air, produce free nitrogen. The main cause of denitrification is due to absence of air, owing to soils becoming water-logged, and not allowing a free passage to this essential material.

The effect of ammonia produced from organic matter only lasts a season. The easily decomposed manures such as dried blood, rape cake, and guano are therefore called quick-acting manures, whilst straw and shoddy are slower in their action.

Organic matter in the soil is valuable in that it increases the capacity for holding water, darkens the soil, thereby causing it to absorb more heat, facilitates the production of tilth, and provides nitrogen. The chief difference between organic manure and artificial fertilisers is the action upon the soil. Artificial fertilisers have very little action, but organic matter causes great improvement in the soil in regard to its texture and water-holding power, and although it is not always needed for the crop, it is important in soil management. The best results are obtained from the happy combination of organic manure and artificial fertilisers.

Phosphorus.—Phosphates are the most important phosphorus foods known for plant life. They promote root

formation, and are specially valuable when root development is required. Generally, it may be stated that the application of phosphates to clay soils is good, but it is less needed on sandy soils. Phosphatic fertilisers are used for all root crops, and are particularly beneficial when drought is likely to set in, because they induce the roots to spread to moister soil. They also hasten ripening processes, and soils deficient in phosphates are usually unsatisfactory.

Potassium.—The absence or low value of potash in a soil affects the colour of the leaves, and the size and weight of grain. The vigour and healthiness are dependent upon the potash supply, and leguminous plants particularly stand in need of this material.

Sodium.—Salts of sodium do not appear to be essential to plant life, yet certain plants give better results with them. They are useful when there is a deficiency of potash in the soil.

Lithium.—The salts of lithium appear to have a toxic effect upon plants.

Calcium.—An essential plant food, in many cases giving vigour and health to the plant. Gypsum is used on soils to counteract the harmful effects of alkali-forming materials in the soil.

Magnesium.—The salts of magnesium in excess are harmful, but magnesium is essential to the life of the plant. Chlorophyll, the green colouring matter of plants, is a magnesium compound.

Aluminium.—It is stated that in small amounts, aluminium compounds are beneficial.

Iron.—The formation of chlorophyll depends upon the presence of a ferric salt, and is therefore a necessary material.

Manganese.—This substance is considered necessary to plant life, but large quantities are stated to be harmful.

It is interesting to note that in a series of experiments described by J. S. McHargue, Agri. Ex. Station, Lexington, Ky., the absence of manganese from a set of pot cultures containing the ten essential constituents of plant food (carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron), caused the plants to make no further growth after the food supply of the seeds was exhausted. The addition of small amounts of manganese to similar cultures induced the plants to assume normal growth. It is stated that manganese functions in the synthesis of chlorophyll and in carbon assimilation.[1]

Sulphur.—An essential food constituent. It occurs especially in cabbages and swedes.

Water, *carbon dioxide*, and *oxygen* from the air also provide food for the plant.

Water supply.—Water plays an important part in plant life, the value of which can be seen by the large amounts of this substance found in plants, which varies from 7–10 per cent. for hay and straw, to 60–90 per cent. for cabbages, potatoes, and turnips.

Water is used by the plant for the process of transpiration. It also plays a big part in causing the solution of many substances in the soil. Water is mainly absorbed by the roots of the plant, and the amount of growth varies as the water supply increases up to a certain point, when excess of water is harmful in that it reduces the air supply to the roots. On moist soils such as clays and loams, the plants usually have large leaves, but on the drier soils the leaves are narrow, and the roots more developed. With copious water a more protracted growth takes place.

[1] *Ind. and Eng. Chem.*, Feb. 1926, pp. 172–175.

Air supply.—All plants need air, and it is essential to fertility. The oxygen of the air is needed by the plant, and is also necessary for the oxidation of the organic matter in the soil.

The nitrogen is not used directly by the plant, but is absorbed by certain bacteria living in the root hairs on the nodules of plants such as clover, lucerne, and vetches. These crops therefore enrich the soil.

The carbon dioxide of the air, usually amounting to about 0·03–0·4 per cent. is absorbed by the leaves and other parts of the plant in sunlight, giving off oxygen and leaving the carbon for use by the plant to build up plant tissue.

As air is needed by the roots, a soil must have an open structure, but it must not be too open, or water percolates too quickly and the plant suffers.

Climate.—Soils vary in their structure and fertility according to their original composition, then as to the climatic conditions prevailing, such as running water, ice, and wind. Climate helps to make the soil, and to decide the crop, and influences the production of the soil. Dry conditions tend to produce plants which are narrow-leaved and tough, whilst a wet climate gives a more leafy type of plant. The latter yields more humus when decomposed, and therefore it is due in no small measure to the climatic conditions as to the character of the soil, for this depends much upon the nature of the organic matter present.

A wet soil is not so good for seeds, but leaf does well. A dry summer suits grain crops, but grass requires moister conditions. A high rainfall tends to wash out nitrates and chalk, and a wet winter will remove the nitrates formed during the summer, causing a loss in the food supply for the next generation of plants. Conversely, a dry, hard

winter will conserve this food supply, and a good spring and summer following a hard winter is good for the growth of plants. The physical condition of the soil is much affected by continued wet weather, making it difficult to work. Frost lightens the soil, makes it easy to work, and benefits tilth. Hot sunshine improves the soil, in that it tends to break it up if it is heavy, and gives increased yields of crops by the additional warmth.

Temperature.—The rate of oxidation of organic matter in the soil is largely dependent upon temperature. The temperature of 98° F. is the best one for this purpose, as above and below this figure the process is slowed up. It also affects the rate of growth, and if too low, so weakens the plant that it may succumb to insect pests.

Injurious factors.—*Soil reaction.*—Generally it is true that plants do not grow well on acid soils, but it is the amount of acidity which is important. A very acid condition does not favour plant growth, and the development of many plants. The cause of this poor growth has been attributed to lack of calcium, to the presence of soluble salts of aluminium and iron, which seem to be toxic, and to the presence of free acid. Ordinary acids, such as sulphuric acid, are distinctly harmful to plants, but most fertile soils have a real acidity measured as a hydrogen-ion concentration. An acid condition of P_H 4·5–8·5 (hydrogen-ion concentration) exists in soils, and an acid condition up to P_H 5·16 is not considered harmful, but even helpful to plant growth. Alkalinity may be even more harmful than acidity, and a P_H of 8·26 causes injury.

It has been pointed out by certain authorities that soil acidity can be classified as follows: (1) Actual acidity of the soil, (2) acidity which may be developed in the presence of neutral salts, due to the liberation by basic

exchange of readily hydrolysed iron and aluminium salts, and (3) acidity which may be developed in the presence of salts of weak acids with strong bases, the base being absorbed by the soil and the acid left.

An acid soil in the chemical sense is not necessarily a sour one from the farmer's point of view, and there is increasing evidence that the harmful effects of some soils are due to the toxic properties of soluble aluminium and iron salts in them, rather than to their actual acidity.

Soils, therefore, may have little actual acidity, but may develop considerable injurious conditions when dressings of certain salts are given.

A satisfactory method to show the presence of true acids in the soil, is to measure the hydrogen-ion concentration as compared with water. The colorimetric indicator method, in which a solution giving varying colours according to the P_H value, has considerable use.

This method is sometimes inapplicable owing to the turbidity of the soil extracts. If, however, the suspension of soil in water be centrifuged, the resulting liquid gives sufficiently accurate results. On the other hand, soils are sometimes infertile by reason of a lack of lime in them. This is called sourness, and is due to a lack of basicity and not to true acidity. Sourness, one of the most widespread defects of soils, is overcome by the addition of lime.

Alkalinity of soils.—Large or frequent dressing of sodium nitrate has a bad effect upon soils, especially clay ones, in view of the fact that the nitrate is used by the plant, leaving an excess of the soda part of the salt to produce alkali.

Apart from the fact that alkaline soils are even worse than acid ones for plant growth, the clay becomes deflocculated by alkalis which makes it revert to the plastic condition in wet weather, and the hard state in hot weather,

and furthermore lime has little or no effect upon this condition.

Sodium nitrate should be used on clay soils in conjunction with fertilisers like superphosphate or ammonium sulphate. Superphosphate contains gypsum, which is an efficient flocculating agent. Soot is also an effective material in these cases, as it causes flocculation and contains ammonium sulphate.

Other substances which cause alkalinity are potassium sulphate, sodium chloride, and other salts of potassium and sodium.

Metallic salts.—The salts of copper, zinc, and lead, ferrous iron, aluminium, and arsenious acid all appear harmful, and to have toxic effects upon plants if they exist in traces in the soil. Lime is the best antidote.

Magnesium sulphate and magnesium chloride are harmful to plant life. Magnesium oxide, on the other hand, has been found beneficial in certain cases, but usually in soils containing lime also.

Losses in the soil.—The chief losses suffered by a soil are denitrification, mentioned previously, the losses by drainage when chalk and plant foods such as nitrates are dissolved out, and the loss of ammonia resulting from the decomposition of nitrogenous organic manure.

The drainage water from soils generally contains considerable quantities of sodium bicarbonate, and in addition, nitrates, sulphates and chlorides of calcium and sodium.

A high rainfall causes the loss of chalk and nitrates, both of which have to be replaced, and the tilth is also impaired.

Drought, frost, and hot sunshine are detrimental to plant life, but are beneficial in that they aid bacterial activity and improve the tilth.

CHAPTER II

FERTILISERS

General.—The term "fertiliser," in ordinary use, is applied to those materials which are added to the soil to supply or increase the constituents of plant food, thereby bringing about a greater fertility. The term in its broadest sense might, however, be extended to any matter which improves the soil, either by rendering its condition suitable for growth, or by making the food resources of the soil more available for the plant. Such compounds as lime, limestone, chalk, gypsum, and even clay or sand, improve soil conditions under certain circumstances, and might be classed as fertilisers, but a better term is that of soil-improvers, confining the term fertiliser to those substances which actually supply plant food.

The distinction between fertiliser and manure is not clearly defined, but, in general, the term manure is used for farmyard and similar products, and fertiliser for manufactured materials, mineral deposits, and by-products of a factory.

It is beyond question that the proper use of fertilisers increases the yield of farm crops, without a decrease in quality, and it has been generally proved by experiment that the best results have been obtained by the combination of dung and artificial fertilisers. Most soils are lacking in nitrogen, phosphate, and potash, hence the need for

supplying these plant foods in a suitable form. It has been estimated that of the amount of nitrogen, phosphate, and potash absorbed annually by the crops of the world, not more than 50 per cent. is returned by the farms themselves, and about 13 per cent. is added in the form of fertilisers. It will be seen that there is a deficit of about 37 per cent., which illustrates the need for replacing them as fertilising materials for good plant growth.

It has been shown that 25 bushels of wheat and 2,500 lb. of wheat straw remove approximately 42 lb. of nitrogen, 7 lb. of phosphorus, and 17 lb. of potassium from an average soil. In addition to these, soils of the better type lose from 200–500 lb. of lime per acre per annum, and with the use of fertilisers this loss may be greater.

Again, the balance between the animal and vegetable kingdoms must be maintained. If too little fertiliser is applied to the soil, the yield and quality of the crops will be lower and will not contain the proper amounts of albuminoids, carbohydrates, and fat necessary for the animals fed on them to be sufficiently nourished. If the amount of fertiliser added is too liberal, the land will become sour, and the crop poorer in quality.

Of the materials associated with plant life, and those which provide food for crops, the most important by far are nitrogen, phosphorus, and potassium. In an efficient fertiliser, these constituents must be in a suitable form for the plant to assimilate them, or in such a condition that by action of the soil, they rapidly become available for the plant.

Soils containing large amounts of calcium, nitrogen, phosphorus, and potassium, are not necessarily more productive than ones holding much smaller quantities. Plants obtain their raw material from the soil solution, and the

concentration of the soil solution, and the rate at which the concentration is maintained, will determine the rate of plant growth. We should distinguish between the total plant food and the available plant food.

In recent years, some important results have been obtained of the effect of very small quantities of substances not usually considered as essential to plant life, and minute amounts of manganese, fluorine, zinc, and iodine have, in experimental water cultures, produced an increase in the growth of plants. The salts of boron in traces are stated to have had a beneficial effect upon leguminous plants. These experiments have not been confirmed by field trials, but this is probably due to the fact that the soil already contains very small quantities of these materials, and the effect of adding more has produced no further increase. These results suggest that the poorness of some soils may be due to the removal of these elements by the continued application of artificial fertilisers.

Organic fertilisers such as rape cake, dried blood, guano, and farmyard manure are extremely valuable in improving the physical condition of the soil, and cannot be regarded as merely supplying plant food. Artificial fertilisers must be looked upon as containing plant food, and as having little or no action upon the texture of the soil, and no value is attached to this action.

Nitrogen, phosphoric acid, and potash are the only ingredients necessary, and artificial fertilisers are valued according to the amount of these constituents they contain, the availability of them for the plant, and their condition for suitable distribution. Some fertilisers contain only one ingredient useful for plant growth; sodium nitrate, calcium nitrate, ammonium sulphate, and calcium cyanamide contain only nitrogen; superphosphate, precipitated

phosphate, and basic slag contain only phosphate, and kainit, potassium sulphate and potassium chloride only potash. Other fertilisers contain two valuable constituents, as is the case with bones and fish meal, which both yield nitrogen and phosphate. Whatever the fertilising agent applied, it is used up in time by cropping, and if it is not renewed, soil exhaustion follows, and the crop fails.

The results of experiments described by Dyer and Shrivell ("The Manuring of Market Garden Crops," 1924) show the need for the continued application of fertilisers. After eighteen yearly applications of dung and mixtures of artificial fertilisers, the treatment was stopped, and cropping continued for five years. The yield of crops gradually declined in the case of those plots manured with dung to about half their previous value, and with artificial fertilisers to about one-third the usual yield.[1]

The value of artificial fertilisers is that they are more direct in their action than farmyard manure and similar products, and are therefore more suited for the circumstances for which they are required. An application of one fertiliser will introduce into the soil only one food material in the quantity required for that particular crop. It must, however, be remembered that if only one plant food is continually applied, it may lead to soil exhaustion of the other nutrient materials which may be in the soil.

Resources of fertilising materials.—*Nitrogen.*—The modern nitrogen fixation processes ensure the supply of nitrogenous fertilisers, if the other sources of combined nitrogen fail.

Phosphate.—In addition to the phosphate deposits of Florida, Tennessee, Tunis, Algeria, Egypt, and Oceania, there are undeveloped deposits in Wyoming, Idaho,

[1] *Journal of the Ministry of Agriculture,* Nov. 1926.

Montana, Utah, British Columbia, Quebec, Russia, Spain, and Natal.

Potash.—Deposits of potassium salts in Germany are estimated at about 21,000,000,000 tons of crude salts, and in addition other deposits are known in Spain, Italy, Sweden, and the United States.

Production and consumption of the chief fertilisers.— In reviewing the production and consumption of the chief fertilising agents, the most remarkable expansion is to be seen in the synthetic nitrogen products. Of the world's consumption of artificial nitrogenous fertilisers for the year ending June 1926, 49 per cent. is represented by synthetic products, 27·5 per cent. by Chilean nitrate, and 23·5 per cent. by by-product ammonium sulphate. The increase in the production of combined nitrogen from all sources for the year 1925 was 64 per cent. above that for 1913, and over the same period the production of nitrogenous fertilisers other than Chile saltpetre shows an increase of 142 per cent. A synthetic ammonia and nitrates plant based on the Haber principle, and established in England, produced 120 tons of ammonium sulphate per day during 1925, and will eventually turn out 800 tons per day. This is equal to 300,000 tons per year, which is almost equivalent to the ammonium sulphate produced from coal gas, coke oven, and shale distillation.

Nitrogen fixation processes supply the bulk of Germany's consumption, and factories at Leuna and Oppau are producing nitrogen to the extent of 450,000 tons annually. During the first half of 1926 there was an increase in the exports of ammonium sulphate from Germany, 208,512 metric tons being sent out, compared with 61,755 metric tons for the first half of 1925.

The report of the British Sulphate of Ammonia Federa-

tion covering the year ending May 31st, 1926, shows that the general production and consumption of nitrogen has increased by 8·5 per cent.

The following figures show the world's production and consumption of nitrogen :—

	1924–5. Tons.	1925–6. Tons.
By-product ammonium sulphate	290,300	305,700
Synthetic " "	254,800	289,000
Cyanamide	115,000	150,000
Nitrate of lime	25,000	30,000
Other forms of synthetic nitrogen	66,000	119,000
" " by-product "	32,000	27,500
Total production	783,500	921,200
Chilean nitrate delivered ..	363,000	324,200
	1,146,500	1,245,400
Estimated total for agricultural consumption	983,100	1,072,000

The increase in the production of forms of nitrogen other than Chilean nitrate is estimated at 21 per cent. The consumption of Chilean nitrate has fallen 10 per cent.

The increased consumption of the synthetic products is due to the decrease in the price of these materials.

The synthetic products of Germany has now reached 600,000 tons of pure nitrogen per annum. This is at present six times the amount being produced in this country, and accounts for 66 per cent. of the world's output of nitrogen other than Chilean nitrate.

Synthetic ammonium sulphate has a white colour and consists of large crystals, and has the advantage over the by-product material because of these properties.

The world's production and consumption of ammonium sulphate is shown by the following figures :—

Production.		Consumption.	
1924–5. Tons	1925–6. Tons.	1924–5. Tons.	1925–6. Tons.
2,756,900	2,973,700	2,757,290	2,958,600

There has been a considerable increase in the consumption in India, China, Japan, and other countries in the East, but some decrease in its use in European countries.

Germany is first in the production of synthetic products, and England follows next in order. In Belgium, the estimated production of ammonium sulphate for 1926 is 100,000 tons, compared with 90,000 tons in 1925, and 64,000 tons in 1924. In addition to by-product ammonia, synthetic products by the Casale process are expected to supply larger quantities.

In 1925, a factory in America was put up with an expected output of 100 tons per day of ammonium sulphate. Seven plants are now at work with a combined output of 275 tons of this salt per day.

In Italy considerable amounts of synthetic nitrogen products are being made, mainly by the Casale and Fauser processes. The total amount of ammonia compounds made in Italy in 1925 was 6,800 metric tons. Two-thirds were obtained by the direct synthesis of atmospheric nitrogen and electrolytic hydrogen. It is expected to double these figures in 1926. Calcium cyanamide is also manufactured in considerable quantities.

The ammonium sulphate obtained by the Fauser process is a dry white, minute, and pure crystal. Ammonium nitrate, ammonium sulpho-nitrate, sodium nitrate, and nitrite are also manufactured.

Switzerland is producing 135 tons per day of anhydrous ammonia by the Casale process.

Norway is also producing synthetic nitrogen products, and a huge scheme for the fixation of atmospheric nitrogen is being launched in New Zealand, using the water power from certain falls. A very extensive marble deposit, containing 98 per cent. calcium carbonate, within a short

distance of the falls gives this process a decided advantage for the production of calcium nitrate, and this scheme promises to be by far the largest one in the Southern Hemisphere.

Chilean nitrate.—In 1913 about 54 per cent. of the world's consumption of nitrogen was supplied from this source, but in 1922 only 23 per cent., and for the year ending June 1926 the production was in excess of the consumption.

	1914.		1926.
Production	2,822,000 tons	..	2,578,000 tons
Consumption	2,629,000 ,,	..	2,092,000 ,,

The chief reason for the existence of this state of affairs is the increased production of other and cheaper nitrogenous fertilisers. It should be noted, however, that a new process for treating nitrate ore by freezing out the pure nitrate of soda, promises a reduction in the cost of production.

Imports of nitrogenous fertilisers into Great Britain and Ireland during 1925:

Ammonium sulphate	151 tons.
Calcium nitrate	101,551 cwts.
Calcium cyanamide	1,020 cwts.
Sodium nitrate	1,626,483 cwts.

The ammonium sulphate produced in Great Britain amounted to 388,000 tons.

Phosphate rock production.—There has been a steady recovery in the world's production of phosphate rock during the last few years, the estimated production for 1925 being 8,621,800 tons, as against 6,814,000 tons for 1923, and 8,095,970 tons for 1924. Mainly the progress is in the American field, the production in 1925 showing a gain of 21 per cent. on the previous year, and reached 3,500,000 tons.

The Tunis and Algerian products declined a little. This is stated to be partly due to competition from Morocco, the output of which rose from 461,000 tons in 1924 to 692,000 tons in 1925.

It has been frequently stated that the Moroccan product is of higher quality than that mined in Tunis and Algeria, and the low cost of mining in Morocco, and the high phosphate content make it a more successful concern.

In Nauru and Ocean Islands the output has steadily advanced.

The consumption of superphosphate manufactured from phosphate rock in America appears not to have increased at the same rate as production. The consumption in the European market appears to be increasing, but generally the employment of superphosphate is below the pre-war standard.

It is to be noted that the English export trade of superphosphate was lower than in 1911, when 151,000 tons were exported, and only 12,214 tons in 1923.

The home consumption in 1923 was 609,000 tons as against 688,673 tons in 1922, and 800,000 tons in 1913.

Basic slag.—The consumption of basic slag in England and Wales was 300,000 tons in 1923.

Phosphoric acid from phosphorus.—An American process used in Germany for the production of phosphoric acid and hydrogen from phosphorus is an interesting one, and consists of producing these substances by interaction between yellow phosphorus and water in the presence of a catalyst.

The phosphorus is obtained from phosphate rock, and blown with steam over the catalyst at 1,000° C. The hydrogen will be used in the synthetic ammonia process,

and the phosphoric acid worked up for concentrated phosphatic fertilisers.

Potash.—The potash consumption in England has increased enormously, and in 1923, 194,508 tons were used. This is twice the pre-war figure. There was a decrease in the imports of kainit and similar materials, but an increase in the higher potash compounds such as potassium chloride and potassium sulphate.

Compound fertilisers.—The exports from Britain of manufactured guano and bone products have increased.

Classification of fertilisers.—Combined nitrogen, phosphate, and potash compounds are usually valued according to their richness in these three constituents.

They are sometimes loosely classified into natural and artificial fertilisers, the natural ones being those produced on the farm itself, and the artificial ones either deposits or manufactured products. Sometimes the term natural is extended to materials such as seaweed, guano, and oil-cake.

Another classification is that in which fertilising materials are separated into general fertilisers—those which contain all the necessary constituents of plant life, typical examples being farmyard manure and guano—and special fertilisers—those containing only one or two constituents. Such compounds as sodium nitrate, ammonium sulphate, potash fertilisers, and phosphates are examples. Still another method of distinguishing them consists in their separation into the following classes :—

1. Nitrogenous.
2. Phosphatic.
3. Potassic.
4. Organic.
5. Mixed.

It might, however, be simpler still to classify them according to the ingredient contained in the fertiliser which gives it its value, and in the following pages they will be considered under the heading of the constituent for which the particular fertilising material is valued.

In some cases there may be a little overlapping, but in general the classification holds good.

The groups of fertilising materials to be considered will now be as follows :—

1. Nitrogenous.
2. Phosphatic.
3. Potassic.
4. Nitrogenous-phosphatic.
5. Nitrogenous-potassic.
6. Phosphatic-potassic.
7. Nitrogenous-phosphatic-potassic.
8. Special.
9. Miscellaneous.

CHAPTER III

NITROGENOUS FERTILISERS

General.—Nitrogen is the most important of all plant foods, and the use of nitrogenous fertilisers usually gives the most profitable results. The application of phosphates and potash do not give nearly so certain effect as do nitrogenous products.

Nitrogen is not taken up by the plant as such, but has to be in combination before it can be used for the purpose of supplying nutrient material to vegetable life.

The form of combination which appears to be the most suitable and readily available, is as nitrate, and these compounds are quicker in their action than any other type of nitrogenous fertiliser, the next in order being ammonium salts, which are rapidly manufactured into nitrates in the soil. Finally, there are the slower acting materials such as animal and vegetable matter, which breaks down gradually into ammonia, and then into nitrate, by action of soil bacteria.

If the soil is well cultivated, sufficiently limed and supplied with organic matter, the soil organisms will bring about these changes, unless other conditions unfavourable to the activity of soil bacteria are present.

Nitrogen promotes growth and gives power to the plant to resist disease and attacks of insect pests. In the early months of the year the bacterial activity is at its

lowest, as cold weather limits the process, and it is therefore the best time to apply some form of inorganic nitrogenous fertiliser for the young plant.

Nitrogen is specially valuable for plants of the cabbage type. The application should, however, cease if there are any signs of flabbiness in the leaf. Nitrate-nitrogen is stated to be better for plants valued for their leaves, and ammonia-nitrogen to be more suitable for potatoes, rice, and similar crops.

Some recent German experiments have shown that even pasture land (where the application of phosphate only has previously been considered essential) has benefited enormously by the application of ammonium sulphate, with smaller amounts of phosphate and potash. The land is limed at intervals, and the method consists of an intensive system of the utilisation of grazing land, and small enclosures receive autumn dressings of phosphate and potash, and a series of top dressings of nitrogenous fertiliser during the spring. Cattle are grazed, and passed from one enclosure to another, and it is claimed that more stock can be fed, and that the food value of the grass is better.[1]

The main function of nitrogen appears to be in the greater development of leaf and stem, and excessive amounts of it will cause the plant to become limp, rendering it susceptible to insect pests. It also tends to delay maturity, therefore crops such as barley which are cut ripe do not require much nitrate, although small amounts benefit this crop.

Cereal crops produce too much straw, and potatoes and similar root crops too much leaf, if excessive amounts of nitrogen is supplied.

Nitrogen in the form of nitrate gives food directly to

[1] *Journal of the Ministry of Agriculture*, Sept. 1926, p. 498.

the plant. Next in order are compounds of ammonium which rapidly change to nitrate by the action of soil bacteria. Protein-nitrogen, amino-acid nitrogen, and amide nitrogen, such as are found in farmyard manure and other materials, are also fairly rapidly oxidised by soil bacteria.

The comparative values of nitrogen in its various forms are as follows :—

Nitrate-nitrogen	100
Ammonia-nitrogen	95
Cyanamide-nitrogen	85–90
Protein-nitrogen	70–80

The nitrogen of the air is fixed by certain soil organisms. Denitrification and consequent loss of nitrogen can also take place under certain conditions.

Attempts have been made to utilise cultures of nitrogen-fixing bacteria for promoting nitrification, but without any marked success.

Sodium nitrate.—The commonest nitrate used as a fertilising material is sodium nitrate, $NaNO_3$. This substance occurs naturally in the rainless regions of Northern Chile, where it forms deposits. In spite of the fact that very large amounts have already been taken from this source, vast areas still remain untapped.

The raw product is known as caliche, and varies greatly in its composition. It is a mixture of sodium nitrate with a little potassium nitrate, a larger amount of sodium chloride, and often sodium sulphate and magnesium sulphate.

The usual raw material contains from 20–50 per cent. of sodium nitrate, 25–60 per cent. sodium chloride, 2–20 per cent. insoluble matter, about 5 per cent. sodium and

magnesium sulphates, and small amounts of iodides and perchlorates.

The commercial salt is obtained by crushing the nitrate ore, boiling it up in water, and recrystallising the salt from the solution. After crystallisation the mother liquor is worked up for iodine by precipitation with sodium sulphite and sodium bisulphite. The crystallised salt contains 95 per cent. or over of sodium nitrate, with small amounts of sodium chloride, sodium sulphate, magnesium sulphate, and in some cases a little potassium nitrate.

The salt containing 95 per cent. sodium nitrate is equal to 19 per cent. ammonia, which is equivalent to 15·6 per cent. nitrogen. A new process for treating the nitrate ore consists of freezing out the pure nitrate of soda from the solution. This method is stated to considerably reduce the cost of production.

An impurity which is sometimes present in sodium nitrate is sodium perchlorate. This material is stated to retard germination if present in more than minute traces.

Application.—As this fertiliser is ready to be absorbed by the plant, it is valuable in cold and wet conditions, to ensure an early growth. For this reason it should be applied as a spring dressing, but not before the crop has sufficiently grown to assimilate it, as it is easily washed out of the soil and lost. It should only be given when needed. Young plants suffering from insect pests are benefited by the application of this fertiliser, which helps the plant by rapid growth to weather these early troubles.

Excessive amounts prolong the period of growth, and favour the production of foliage rather than seed. They also tend to produce large roots of poorer feeding value than those grown with less nitrate, and applications for

the early ripening of seed or fruit should be given with caution.

Large or frequent dressing of this fertiliser has an injurious effect upon the tilth, especially upon heavy soils, owing to the production of basic matter when the nitrogen has been used up by the plant. Some of the soda is retained in the soil as sodium hydrogen carbonate (bicarbonate). Part of this reacts upon the potash compounds in the soil, liberating a certain amount of potash which becomes available for the plant, and part acts upon the clay, tending to change it into the sticky deflocculated condition. Ammonium sulphate has an opposite effect, and a good plan to prevent this deflocculation is to use a mixture of equal parts of sodium nitrate and ammonium sulphate, instead of the nitrate alone. A mixture of the nitrate and superphosphate is also efficacious, as well as providing phosphates which must be renewed from time to time. Dressings of lime will remedy this deflocculated condition of the soil, and soot is also effective. Sodium nitrate can be used for any crop, and is especially valuable for leaf crops such as cabbage, kale, hay, and rape. It imparts a dark green colour to the leaf, and gives greater size to it, but if applied in excess tends to make the plant flabby and lay it open to attacks by fungus.

In storing sodium nitrate, it must be kept dry, as in a moist atmosphere it tends to become lumpy and must not be applied in this condition.

It is poisonous to animals, and cattle should not have access to it. The amounts of this fertiliser to apply will vary for particular crops and conditions, but usually from $\frac{1}{4}$–1 cwt. per acre is applied in the spring to cereal crops. For meadows from 2–3 cwts. per acre is often applied in two or three dressings. Mangolds and cabbage can take

liberal amounts, and 4 cwts. or even more may be used for early cabbage.

For turnips, swedes, and potatoes, about 1 cwt. per acre with other fertilisers gives good results.

Little, if any, sodium nitrate should be used for fruit trees, as it tends to produce woody growth at the expense of the fruit.

Ammonium nitrate.—This ammonium salt is not suitable for fertilising purposes owing to its hygroscopic and explosive properties. The B.A.S.F. have now made potassium ammonium nitrate and ammonium sulphate nitrate (Leuna saltpetre). These doubls salts are similar in their action to Chilean nitrate, but have the advantage that their nitrogen only costs the same price as ammonia nitrogen.

A method has been put forward for producing a non-hygroscopic fertiliser from ammonium nitrate, by mixing solid ammonium nitrate with solid ammonium sulphate in the presence of from 3–5 per cent. of moisture.

Commercial ammonium nitrate contains 96 per cent. ammonium nitrate, which is equal to 33 per cent. nitrogen.

Ammonium sulphate.—When organic nitrogenous materials are destructively distilled, the nitrogen is to a large extent expelled as ammonia, and when coal is distilled for coal gas ammonia is a valuable by-product obtained in the purification of the gas, and this is an important source of the supply of ammonium compounds. Coke and shale also produce ammonia when dry distilled. The gases from the distillation are condensed when the ammonia is found in the ammoniacal liquor produced.

The Mond gas process, which consists in blowing in air and steam during the distillation of the coal also produces ammonium compounds, and this process gives larger

quantities of ammonia from the nitrogen in coal than any other method. In the distillation of coal for coal gas only about 20 per cent. of the nitrogen is obtained as ammonia, but in the Mond gas process about 60 per cent. of the nitrogen is recovered as ammonia.

Peat which has been partially dried has also been distilled to produce ammonia, and it is claimed that as much as 30 lb. of ammonia calculated on the dry material has been obtained. The great difficulty in this process has been the drying of the peat, which contains large quantities of moisture.

A British patent describes a method of obtaining a fertiliser from peat. The material is partly dried and granulated, and may be mixed with sawdust, lime, waste tan bark, or other material, and then further dried. Peat, coke dust, powdered coal or coke, charcoal, sawdust, tan and lime may be mixed with the peat to form a composite fuel, or the dried peat may be distilled for ammonia, and ammonium sulphate obtained mixed with crude peat for use as a fertiliser. The ammoniacal liquor produced by the distillation of coal and other materials is usually distilled with steam, and the distillate mixed with lime. This product is steam distilled, and the volatile matter, consisting mainly of ammonia, is mixed with sulphuric acid to form ammonium sulphate, which substance is crystallised from the solution.

Formerly the ammoniacal solution was directly neutralised with sulphuric acid, but this method introduced certain impurities into the product which are injurious to plant life. One impurity, ammonium thiocyanate, is toxic to plants, but the modern material seldom contains this substance.

Another impurity which was sometimes introduced

in the acid used was arsenic, which is very harmful to plants and animals, and the acid used must be free from this poison.

On an average the yield of ammonium sulphate in a gas works is 22½ lb. per ton of coal. The Mond gas process gives a yield of from 75–85 lb. of ammonium sulphate.

In modern times the nitrogen fixation processes are accounting for large amounts of ammonium sulphate, and in the future these methods will produce still larger quantities.

These synthetic processes were developed enormously during the war and since, and in many countries thousands of tons are being produced annually. Germany now imports no Chilean nitrate. Several processes are in use, and the particular method depends upon the locality, labour, and the power available.

The Haber process consists of the direct synthesis of ammonia from nitrogen and hydrogen, and is carried out by bringing a mixture of the pure gases in the proportion of 1 volume of nitrogen and 3 volumes of hydrogen under a pressure of 200 atmospheres in contact with a catalyst such as iron at about 600° C.

About 8 per cent. by volume of ammonia is produced, and this is removed from the gas by washing with water.

Ammonium sulphate is produced by a special method in German works by interaction with calcined gypsum and carbon dioxide. The ground calcined gypsum is put into a vat with the wash water from previous operation. Ammonia gas is passed into the suspension until 2–3 per cent. ammonia is in the solution. Carbon dioxide is now passed in at 60° C. until the solution contains from 0·3–0·5 per cent. ammonia. The Badische Co. use a suction filter to obtain the solution free from the suspended calcium

carbonate which is formed. The Otto process consists of a special reaction column, gypsum and water being introduced at the top, and the ammonia and carbon dioxide are forced in together under pressure at the bottom. The liquid, after filling troughs in the column, flows over and falls to the bottom in the form of a hot saturated solution with calcium carbonate suspended in it.

The mass is cooled, and consists of ammonium sulphate crystals and calcium carbonate. The supernatant liquid is returned to the top of the column with more gypsum, and the ammonium sulphate is separated from the mixture by using small amounts of water, filtering, and recrystallising.[1]

The Claude process for the production of ammonium compounds uses water gas as the source of the hydrogen. It is generated from bituminous coal, is purified, and freed from tar and other gases. The hydrogen is burnt in air in a combustion chamber to yield a mixture of hydrogen and nitrogen. The mixed gases are then compressed to 1,000 atmospheres and sent to catalyst bombs, where ammonia is synthesised. The ammonia solution obtained contains 20 per cent. by volume, and ammonia is produced from it by liquefaction by water cooling.

Ammonium chloride is the salt usually obtained in this process, and a factory in Cumberland expects to produce 50,000 tons of ammonium chloride per annum.

Another method consists in the direct synthesis of nitric oxide from air in the electric arc, followed by conversion into nitric acid and nitrate.

A nitrogen fixation method depending upon the reaction between nitrogen and calcium carbide forming calcium cyanamide is also in considerable use. The

[1] *The Chemical Trade Journal and Chemical Engineer*, Oct. 22nd, 1926.

cyanamide can be used directly as a fertilising material or decomposed by steam with the production of ammonia. This method will be considered under the production of calcium cyanamide, which is an important fertiliser.

Ammonia may be oxidised to nitric acid and nitrate by catalytic oxidation. In the Ostwald process ammonia is oxidised by heating air containing 8 per cent. by volume of ammonia, in the presence of a platinum catalyst, when nitric oxide is produced. This gas is passed into absorption towers containing water, where nitric acid is obtained.

Partington uses oxygen and ammonia, and obtains a higher percentage of oxidation products.

Ammonium sulphate sold for fertilising purposes contains from 20–21 per cent. of nitrogen.

The British Sulphate of Ammonia Federation have recently brought forward a simplified method of pricing ammonium sulphate by guaranteeing a minimum percentage of 20·6 of nitrogen, equivalent to 25 per cent. ammonia, for the neutral quality, instead of selling on the basis of 21·1 per cent., with a reduction in price for any deficiency. The bulk will be from 20·9–21·1 per cent.

It is guaranteed to contain 20·6 per cent. by weight of nitrogen, and not more than 0·025 per cent. free acid, and is termed neutral quality.

Application and value of ammonium sulphate.—After the nitrates, this material is the most rapidly acting nitrogenous fertiliser. The change into nitrate takes place very quickly if conditions are favourable. Its action resembles that of sodium nitrate, and there is little to choose between them as actual fertilisers. The choice will therefore rest mainly upon price and circumstance. Sodium nitrate is quicker in its action than ammonium sulphate, which must first undergo nitrification in the soil

but the latter is steadier in its action and extends over a longer period. As the concentration of nitrogen in the sulphate is higher, the total dressing required will be somewhat less than that of the nitrate—about $\frac{3}{4}$ cwt. against 1 cwt.

The continued use of ammonium sulphate uses up lime in the soil, and produces harmful effects if the lime content is very low, for an acid soil will result with injurious effect on crops. It, however, takes a considerable time to obtain these effects and will not take place if the usual practice of applying lime at intervals has been followed.

Results at Rothamsted have shown that 1 cwt. of ammonium sulphate removes about 50 lb. of lime or 0·002 per cent. on the top 9 in. of soil. The sulphate reacts with calcium carbonate giving rise to calcium sulphate and ammonium carbonate. The calcium sulphate is washed out of the soil and the ammonium carbonate absorbed by the soil constituents.

Ammonium sulphate, unlike sodium nitrate, is not washed out of the soil, and in consequence the former is much in favour in certain circumstances, especially as regards its suitability for shallow-rooted plants, and the tendency to remain in the surface layer is a decided advantage over sodium nitrate.

Ammonium sulphate is usually safer than sodium nitrate for winter and early spring dressings, as it will survive considerable rainfall.

With applications of ammonium sulphate it is usually necessary to add other plant food containing potash, but with sodium nitrate this does not appear to be so frequently necessary.

A suitable dressing of ammonium sulphate is from 1–2 cwts. per acre, and it can be used as a top dressing or drilled in with superphosphate. As is the case with

sodium nitrate, it must be counted as lost if not used up by the growing crop.

Applications at Rothamsted have given remarkable increase in the crop of wheat, and it is a most suitable fertiliser for dressings on land containing young wheat.

If kept for some time, ammonium sulphate is apt to become lumpy, and care must be taken that lumps larger than will pass through a ¼-in. riddle are not used, as such lumps will often kill plants if they come in actual contact with them.

Leuna saltpetre.—Mention should be made of a concentrated fertilising material of German manufacture, which consists of a double salt of ammonium sulphate and nitrate called Leuna saltpetre, B.A.S.F. It is stated to be similar in its action to Chilean nitrate.

Ammonium chloride.—In the Claude process for the synthesis of ammonia, it is advantageous to obtain ammonium chloride as the final product. It has been found by experiment that ammonium chloride has given as good result as sodium nitrate, and a little better than ammonium sulphate when applied to a wheat crop, as high a weight of grain being obtained as with the nitrate.

It should be remembered, however, that chlorine adversely affects some crops, and excess is harmful.

Calcium nitrate.—This material, also known as Norwegian saltpetre, is a product of the Norwegian nitrogen fixation industry. The process is carried out at Notadden in Norway, and at Niagara. The method is that by Birkeland and Eyde, and consists in sucking air into a furnace chamber containing a flaming arc produced between copper tubes cooled by water circulation, at a temperature of 3000–3500° C. The gases produced contain

from 1·5–2 per cent. nitric oxide. They are cooled when nitric oxide is converted into nitrogen peroxide. The gases consisting of about 2 per cent. nitrogen peroxide and a little nitric acid are passed through absorption towers where the nitric acid and some peroxide are absorbed by water. Nitric and nitrous acids are formed, and eventually nitric acid. The gas is afterwards passed into a 2 per cent. caustic soda solution to absorb any remaining acid. About 10 per cent. only of nitric oxide and nitrogen peroxide remain in the gas before passing it into the alkali. The dilute acid solution is concentrated, and treated with limestone, and the liquid evaporated until its specific gravity is 1·9, when it is run on to shallow trays. It is then ground up as a coarse powder, which usually consists of a basic nitrate containing about 75 per cent. calcium nitrate, $Ca(NO_3)_2$, and gives approximately 13 per cent. nitrogen, equivalent to 15·8 per cent. ammonia.

The acid can be used to make sodium nitrate by neutralising with soda ash, or ammonium nitrate by neutralising with ammonium hydrate. The calcium nitrate is deliquescent, and in consequence must be used directly the air-tight tins are opened. Much loss will occur if the material is stored unless care is taken to protect it from the atmosphere.

It has been suggested that if mixed with two and a half times its weight of dry or calcined brick or slate, or with calcined gypsum, it will be rendered suitable for spreading on the land and prevents caking.

A similar product to calcium nitrate has been manufactured in Germany. It is nitrate of lime, B.A.S.F., and contains 15·5 per cent. nitrogen. It is stated to be better than Chilean nitrate in its action.

Calcium nitrate is used in the same amounts as sodium nitrate, over which it has certain advantages in that it gives lime to the soil and does not make clay coils sticky.

Lead nitrate.—Water cultures, soil cultures, and field experiments have shown lead nitrate as a source of nitrogen to be equal to sodium nitrate. It gives a deeper green to the leaf than is the case with the sodium salt.

No lead was found in the plant or the soil by extraction with water. The soil absorbs the lead, and destroys its toxicity.[1]

Calcium cyanamide.—This material, first used as a fertiliser in 1901, is usually prepared by the cyanamide process, in which calcium carbide produced from lime and coke in the electric furnace is made to combine with nitrogen obtained from air, and containing only very small quantities of oxygen. This takes place at a temperature of about 1200° C. The crude product contains calcium cyanamide and graphite, and is known as Nitrolim. Its nitrogen content is usually from 18–20 per cent. When treated with water to remove unchanged carbide, it is known as cyanamide, and is used as a fertiliser. A product known as lime nitrogen, and containing calcium chloride, was also placed on the market for use as a fertiliser, but it lost value when exposed to air.

The commercial products are fine, nearly black, powders, with an alkaline reaction and an odour of calcium carbide. They contain considerable impurities, and only from 48–58 per cent. calcium cyanamide, 16–30 per cent. lime, 12–16 per cent. carbon, 2–4 per iron oxide, and 4–7 per cent. sand.

Pure calcium cyanamide should contain 35 per cent.

[1] Berry, *J. Agr. Sci.* xiv, 58–65 (1924).

nitrogen, but the commercial forms contain only about half this amount, the rest being lime and graphite.

These earlier products contained impurities such as dicyano-diamide and similar substances, which have a toxic action on plants, and a depressing effect upon soil bacteria.

The modern form of this fertiliser is stated to be a great improvement upon the earlier Nitrolim, and to be free from the defects of the older material. The tendency to dustiness has been overcome by a method of oiling, and the liability to contain dicyano-diamide reduced. The modern product is guaranteed to contain 19 per cent. nitrogen and 60 per cent. lime, 22 per cent. of which exists as free lime and hydrated lime, and 38 per cent. in combination as calcium cyanamide.

It is sold at a cheaper rate per unit of nitrogen than ammonium sulphate, the price in June 1926 being £10 6*s*. per ton. Fifteen factories are now producing this fertiliser, and 800,000 tons are stated to be sold annually.

The lime content has proved advantageous in meeting the lime shortage of certain soils. As a rule it is very little inferior to ammonium sulphate, but has proved better in soils deficient in lime.

Calcium cyanamide is not soluble in water, and is decomposed in the soil into urea, then into ammonia and calcium carbonate, the ammonia being finally converted into nitrate for plant food.

Application.—This fertiliser does not appear to be so good as nitrate for leaf crops, but is better for turnips. It is not so suitable for wheat grown continuously on the same land. Field experiments show it to be nearly equal to ammonium sulphate. It is not so suitable as the sulphate for top dressings, as it is somewhat slower in its

action, and for this reason should be applied early and harrowed in.

It can be safely mixed with basic slag, but causes superphosphate to revert to the insoluble condition, unless the mixture of these materials is at once put on to the land.

Its manurial value is about 85–90 compared with nitrate at 100, and more will be required than that of the nitrate.

Calcium cyanamide can be converted into ammonia by adding soda ash to produce sodium hydroxide, and steam distilling, and as a means of obtaining ammonium sulphate, and for the production of urea, this material promises to have an important future.

Cyanides from air.—Most methods are based upon the reaction between sodium carbonate and carbon in the presence of iron as catalyst heated in air at a temperature of 950° C. This may be a source of cheap ammonia compounds, for when sodium cyanide is boiled with water ammonia is produced. Reactions—

$$Na_2CO_3+4C+N_2=2NaCN+CO.$$
$$4NaCN+4H_2O=2NH_3+Na_2CO_3+H_2O+CO.$$

Urea.—This material, which shows great promise as a fertiliser, is being produced on a technical scale from calcium cyanamide, which is first converted into free cyanamide by means of carbonic acid, and then the cyanamide is hydrolysed by treatment with sulphuric acid of a specific strength. Urea-sulphuric acid is the product, from which urea is separated by a patented process, and the sulphuric acid recovered.

Crude urea and commercial cyanamide have a tendency to depress ammonia and nitrate formation, due to the presence of impurities such as dicyano-diamide and

guanyl-urea sulphate. Experiments have shown that these compounds do not affect germination or plant growth if in moderate quantities, but small amounts of either retard nitrification.

Pure urea has no harmful effects, and if made from ammonia and carbon dioxide, or as a pure salt by the method described above, it is free from these impurities, and gives as good results as sodium nitrate or ammonium sulphate. It is very quickly converted into ammonium carbonate in the soil.

Urea is, however, hygroscopic, and in this respect is inferior to ammonium sulphate.

Industrial urea, B.A.S.F., contains 46 per cent. nitrogen, which gives great economy in transport charges.

Application.—Urea is stated to be very good for sugar beet, tobacco, hops, vines, and garden produce, and field experiments with this material and sodium nitrate applied to sugar beet and potatoes, show it to be a little superior to the nitrate.

Soot.—A useful fertiliser obtained by the combustion of coal or wood. It consists of the minute particles of carbon, tar, and ash of imperfect combustion, and the ordinary material contains these constituents together with small amounts of nitrogen and sulphur compounds. It varies tremendously in its composition.

Domestic soot contains more nitrogen than that produced in boilers, and the former material is more bulky than the factory variety. The amount of nitrogen in domestic soot varies from 2·5–11·0 per cent. and in boiler soot from 0·5–1·25 per cent.

The best varieties are lighter in weight than the poorer factory type, and there is a distinct connection between the weight per bushel and the nitrogen content.

Average soot contains 1·8–2·0 per cent. nitrogen and weighs from 40–43 lb. per bushel.

One of good quality, containing 4 per cent. nitrogen, will weigh 24 lb. to the bushel, and not more than 28 lb., and a very good sample, with 7 per cent nitrogen, will weigh about 15 lb. to the bushel.

The nitrogen in soot is mainly in the form of ammonium salts, and a good specimen will contain about 95 per cent. of its nitrogen in this combination. For this reason it is a quick-acting fertiliser.

Application.—It is valuable in garden work as its dark colour increases the absorptive power of the soil for heat rays, and its application will often raise the temperature from 2–3 degrees.

It renders heavy soil more friable, is a powerful insecticide and fungicide, and is distasteful to slugs and snails.

Soot is a valuable top dressing for wheat, and 6 cwts. of good material is equivalent to 1 cwt. of ammonium sulphate.

It is stated to improve the colour of roses, and it is also used considerably in the manurial treatment of hops in Kent.

It should be stored in a dry shed, and should never be mixed with lime, or ammonia will be liberated and lost.

Dried blood.—The dried blood from slaughter-houses is sometimes used as fertiliser. To dry the material several methods are resorted to ; in some cases it is dried at steam heat, and the product ground to powder, in others the blood is coagulated by heating it with a small amount of a ferric salt to dry it. The most satisfactory process is to dry it by means of lime. The lime, to the extent of 2 per cent., is mixed with the blood to form a cake which can be

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readily dried in air. The product of this method is stated to be superior to that obtained by using a ferric salt, as it decomposes more rapidly in the soil, and it also contains a small percentage of lime. The amount of nitrogen in blood is about 1·5 per cent. in sheep's blood, about 6 per cent. in clotted ox blood, and from 12–14 per cent. in a carefully dried sample.

Many varieties of ordinary dried blood contain only 8 per cent. of nitrogen, but the best kinds of the commercial article have a nitrogen content of from 11–13 per cent. Phosphoric acid is also present in small quantities.

Dried blood is chiefly used for the manufacture of compound or mixed fertilisers.

Its nitrogen is in a readily available form, and it is stated to be specially valuable for roses, carnations, and grapes.

A U.S. patent describes a product made from waste slaughter-house materials, in which the waste blood-water is allowed to ferment in the presence of scrap iron. Fermentation is induced by the introduction of a little fresh blood or a little yeast. The fermented liquor is used for cooking other waste materials such as manure and packing-house garbage, then the whole is dried for use as a fertiliser.

Oil-cakes.—These materials are generally used as cattle food, but some of them, for various reasons, are unsuitable for this purpose, and are often prepared for use as fertilisers. They are the by-products of the process for obtaining oil from seeds by pressing. The later methods involve the use of a solvent extraction process, instead of pressing the seeds. These modern methods obtain more oil, and leave the cake in a more suitable state for use as fertilisers. Benzine is the solvent usually employed.

Among the cakes used as fertilising substances, castor cake, rape-seed cake, and cotton-seed cake are the common ones.

Rape cake is used only for its nitrogen content, and will be considered here, but cotton-seed and castor cakes contain appreciable amounts of potash and phosphoric acid, and will be dealt with under nitrogenous-phosphatic-potassic fertilisers.

Rape cake—Rape meal—Rape dust.—Rape cake is manufactured from *Brassica napus.* The seed contains about 40 per cent. of oil, and the manufactured cake often contains up to 10 per cent. of oil. The cake is obtained by the pressing method and by the benzine extraction process, but the latter is better, and is now more common, as it lowers the oil content of the cake.

Rape meal and rape dust are respectively the broken up and powdered cake.

Indian rape cake contains about 5·5 per cent. of nitrogen.

Application.—Rape dust has given good results when used for barley and wheat. It is used as a top dressing, and it rapidly yields nitrogen to the soil, but it is not so good a fertiliser as fish guano, although the price per unit of nitrogen is often higher than that of the guano.

Rape meal and dust have given good results with cereals and roots.

Shoddy.—A waste wool material is known by this name. It is obtained during the manufacturing processes in wool factories, and consists of wool which is unsuitable for spinning, and old woollen materials. Silk waste is a similar product.

Its value depends upon its fineness of division, and upon the amount of wool it contains, as cotton, which is often present, contains no nitrogen.

Pure wool shoddy contains 15 per cent. nitrogen, but the usual quality varies in its nitrogen content according to the treatment it has undergone, and the amount of dirt, water, cotton, and oily substances left in it.

It has long been used as a fertiliser, and is usually divided into three classes according to the amount of nitrogen present.

The high grade material contains from 12–13 per cent. nitrogen. It is clean, sometimes coloured, and includes carpet waste. It is often used as an ingredient in the manufacture of compound fertilisers.

A medium quality contains from 4·5–7·5 per cent. nitrogen, and is made from wool combings, wool waste, flock dust, and poorer cloth clippings. This quality is largely used for hop manuring.

The low-grade shoddy contains from 2·5–3·0 per cent. nitrogen, and is of low value as a fertilising material.

The sale and purchase of the material on the basis of unit value, is still considered the best method to deal with it.

Wool dust contains from 3–4 per cent. nitrogen.

Application.—Shoddy is a useful fertiliser, but is less active than meat meal or dried blood. It has considerable physical effect upon the soil, and this adds to its value. It is a slow-acting fertiliser, but has given beneficial results on many crops, and is especially valued for hops and market garden produce, 1–2 tons per acre being ploughed in during the winter.

Shoddy has also given good returns when used for mangolds, swedes, and barley, and Rothamsted experiments show that on an average, 10 cwts. of this material per acre has given as much increase in crop as 16 tons of farmyard manure.

Dissolved shoddy is sometimes prepared by acting upon it with sulphuric acid. It has been used directly as a fertiliser, and as an ingredient in compound fertilisers.

Hoof and horn meals.—The value of these fertilising materials depends upon their fineness of division, as if in large pieces they have practically no value. The powdered horn obtained in the manufacture of combs contains 15 per cent. nitrogen.

High-grade horn shavings and fine ground hoof yields from 12–14 per cent. nitrogen. Hoof and horn meals usually contain 12·5 per cent. nitrogen. An American sample of hoof and horn meal gave 13·25 per cent. nitrogen, and 1·8 per cent. phosphoric acid, and one much admixed with bone contained 10 per cent. nitrogen, and from 20–25 per cent. phosphate.

Horns are sometimes treated by either roasting or steaming, thereby making them brittle, that they may be easily ground up.

These materials are slow-acting fertilisers, and decompose in the soil very sluggishly. They are used by market gardeners.

Leather scrap—Leather dust.—Scraps of leather are stated to have value as fertilisers, and the scraps obtained in making gloves, and material of a similar type are sometimes put into the soil with cabbage plants. They are also used as a fertiliser for plum trees.

They have a good physical effect upon the land, in addition to any nitrogen, which usually amounts to from 4–6 per cent., they may supply to the plant.

Leather dust, although containing about 3·5 per cent. nitrogen, has little or no value as a fertiliser. An improved product contains from 5–6 per cent. nitrogen.

A process for rendering the nitrogen in leather more

available, and to produce a fine powder, consists in its treatment with acid, but it is doubtful whether it has much fertilising value.

This product and leather dust are sometimes put into mixed fertilisers to increase the nitrogen content.

Hair.—This material is not greatly valued as a fertiliser, owing to its tendency to matt and remain in this condition for a long time. It does not break up easily, and although it contains about 9 per cent. of nitrogen, it is not valued so highly as feathers.

In the treatment of hides for the removal of hair by soaking in water, then subjecting them to the action of lime and scraping, the solution obtained is allowed to settle, and the sediment containing hair and lime is air dried. This material is used as a fertiliser containing hair and lime.

The short hair of South American hides removed by the sweating process in tanneries, is treated with fumes of hydrofluoric acid, which are given off when phosphate rock is subjected to the action of sulphuric acid, to form acid phosphate. By this means the nitrogen in the hair is converted into ammonia from which ammonium sulphate is formed, and utilised as a fertiliser.

Feathers.—These resemble hair in composition, and they contain from 8–9 per cent of nitrogen. They are used in Ireland as a fertilising material, and 20–25 cwts. per acre have given good results in some hop gardens.

The smaller feathers are considered more valuable than larger ones, as the latter take a long time to decompose in the soil.

Greaves.—This is the waste material sent out by soap boilers. It is the refuse left after making tallow or soap grease, and is similar in composition to meat guano, but inferior to it.

The lower grades only are used as fertilisers. It is very variable in composition, but has been used successfully for hops, fruit, wheat, and other crops.

Rabbit waste.—This usually consists of the external waste of rabbit carcases, such as the ears, feet, and tail. It contains on an average from 10–12 per cent. nitrogen, with some phosphate.

It is stated to be a useful fertiliser, but would be much improved if it could be broken up.

Tannery refuse.—See Hair and Leather.

Sewage sludge.—A material deposited during sewage purification. It is prepared by settling or precipitation processes, and the most valuable soluble constituents are lost.

Sometimes the sludge is mixed with lime, and pressed into cakes. These cakes contain on an average 20 per cent. organic matter, 30 per cent. mineral matter, 1 per cent. nitrogen, and 1 per cent. phosphoric acid.

A process whereby the fat is extracted from the sludge yields a product containing 2·5 per cent. of nitrogen.

Sewage sludge, especially if it contains lime, has some fertilising value, but the action is slow and appears at its best in moist districts. Mixed fertilisers containing this material have given good results.

A United States patent describes the production of a fertiliser from sewage sludge, by mixing it with garbage and other waste, incinerating the mixture, and washing the gases produced in sulphuric acid, when ammonium sulphate is produced. This is removed by crystallisation, and added to the ash for use as a fertiliser.

Activated sludge.—The newer aerobic sludges are better than the ordinary sludge, and show promise of being good fertilisers.

The method for their production consists in blowing air through the sludge thereby greatly improving it, and an average activated sludge contains 6 per cent. of nitrogen and 4 per cent. phosphoric acid.

Another process consists in agitating sewage in contact with air and an accumulation of its own sludge. The sludge particles bearing nitrifying and other bacteria, circulate, causing oxidation and flocculation. Lime was added, but recently sulphur dioxide precipitation has been suggested, which produces a partially disinfected sludge containing recoverable fats, and having fertilising value.

A comparison of the fertilising value of activated sludge with other materials for use in tobacco culture shows that the sludge compared favourably with dried blood, was somewhat better than cyanamide and sodium nitrate, and was considerably superior to ammonium sulphate.[1]

A British patent describes a method to improve activated sewage sludge for use as a fertiliser by mixing it with chalk, Thomas meal, magnesite, or other insoluble neutral salts, and filtering the mixture.

Peat.—Peat, either in its natural condition, or treated, appears to have little fertilising value. The natural material contains 1·9 per cent. nitrogen, and this substance, or peat treated with sulphuric acid, gave no appreciable increase in the growth of barley on a soil which yielded large returns from the applications of sodium nitrate or ammonium sulphate. A French method for making peat suitable as a fertiliser consists in treating it with ammonia liquor from gas works or coke ovens. The phenol and similar compounds in the ammonia have value as a germicide, and peat containing 12 per cent. organic nitrogen has been made from material containing only 2 per cent. nitrogen.

[1] H. D. Brown, Provincial Board of Health, Ontario, Canada.

Relative values of nitrogenous fertilisers.—The varied conditions and types of soil make any valuation of a fertiliser merely a general one, for one particular material may suit a certain soil and be not nearly so good on a different one.

Generally, however, for the average soil, nitrates are the most active, and give more corn and straw than ammonium sulphate, but in a wet season the sulphate may be better. On pasture land, the nitrate is usually better, but with potatoes the ammonium salt is superior. Good results with ammonium sulphate appear to be more dependent upon the supplies of potash and phosphates in the soil than is the case with nitrate.

Cyanamide and urea under suitable conditions are little inferior to ammonium sulphate, and in some circumstances give equal results. In one series of field experiments, in which oats were given equivalent amounts of ammonium chloride, sodium nitrate, ammonium sulphate, and urea, the following relative amounts of grain and straw were obtained :—

GRAIN

Ammonium chloride	182
Sodium nitrate	175
Ammonium sulphate	167
Urea	154

STRAW

Ammonium chloride	186
Sodium nitrate	174
Ammonium sulphate	161
Urea	154

and another set of experiments showed that calcium

nitrate, ammonium nitrate, ammonium chloride, and urea were as beneficial as sodium nitrate and ammonium sulphate.

The organic nitrogenous fertilisers have marked effect upon the physical condition of the soil, and act differently according to the type of soil. In clay soils they decompose very slowly, and shoddy, oilcake, and even farmyard manure usually give little plant food during the first year. These materials are the more active as their fineness of division, and when applied to open soil.

The average relative value of some nitrogenous fertilisers under normal conditions and on ordinary soils has been given as follows :—

Nitrate	100
Ammonium salts	95
Cyanamide and Urea	90
Dried blood	70
Fish guano	60
Castor meal	60
Wool dust	25
Ground leather	10
Hair	10

These figures can only be a general guide, as conditions and soils play important parts.

CHAPTER IV

PHOSPHATIC FERTILISERS

General.—These materials are indispensable for certain crops, and have a marked beneficial effect upon soil bacteria. It is stated that an actual deficiency of phosphoric acid can cause more injury to crops than an equal deficiency of nitrogen.

The particular value of phosphatic fertilisers lies in their property of maturing roots and stems, by producing woody growth. They specially develop root formation, enabling the plant to take nourishment from the soil in the early stages of its life. For this reason they are valuable on clay soils where roots do not form readily. The application of phosphates causes the roots to spread and break up the soil, thereby improving it by rendering it more easily penetrated by air and water. If there is a deficiency of phosphates the roots become dwarfed.

In the later stages of plant life they increase the quality and number of seeds and fruits, and hasten ripening.

The proportion of grain to straw is generally increased, and the period of ripening shortened.

Phosphates are indispensable for crops of the pea and bean type, and are valuable for cabbages. They are generally more needed on clay lands than on sandy ones.

They greatly improve all root crops such as swedes, turnips, potatoes, and mangolds, and barley responds to

their application. They are very good when there is continual bad weather, as by their application the ripening process is accelerated.

The use of a phosphatic fertiliser much improves grass land, especially if employed in conjunction with farmyard manure. The effect of phosphate is most marked with hay, and the best pastures are those which are richest in this material. Poor clay pasture lands have been enormously improved by the application of phosphatic fertilisers, especially by basic slag, and many soils lacking in lime and phosphates fail to produce good crops. Phosphates do not wash out in the drainage water, and are, therefore, not lost during wet conditions.

The best results with phosphates appear to be when employed in conjunction with farmyard manure or similar material.

The main sources of phosphatic fertilisers are phosphate rock, superphosphate, basic slag, and bones.

In recent years there has been a considerable increase in the consumption of phosphate rock as a fertilising material.

Mineral phosphates.—The mineral phosphates are very widely distributed, and they occur in a variety of forms, including apatite, phosphorite, coprolite, phosphatic chalk, guano, bat guano, and phosphatic guano, with a phosphoric acid content as low as 5 per cent. for some types of bat guano, 18–39 per cent. for apatites, 7–34 per cent. for guano, 17–39 per cent. for phosphorites, 7–34 per cent. for coprolites, 7–40 per cent. for phosphatic guano, and 20–27 per cent. for types of phosphatic chalk.

The phosphoric acid occurs in most of these minerals as tricalcium phosphate, that is, an insoluble phosphate.

The following are brief descriptions of the most important mineral phosphates.

Coprolites.—In England, these minerals are found in Buckinghamshire, Cambridgeshire, Bedfordshire, Norfolk, and Suffolk, and the calcium phosphate varies between 50 and 77 per cent. They also occur in France, and these contain from 38–44 per cent. calcium phosphate. The Russian variety contains 46 per cent. calcium phosphate.

Rock phosphates.—In America the Florida deposits are important ones, and consist of hard rock phosphates containing from 78–80 per cent. tricalcium phosphate, and pebble phosphate, in the form of rounded pebbles containing 70–79 per cent. of tricalcium phosphate. There is also a soft clay phosphate with a phosphate content of from 40–60 per cent. All are used in the manufacture of superphosphate. Extensive deposits of Tennessee brown rock phosphate are also worked, and these are estimated at 45,000,000 tons. They are covered with earth and clay, which is removed, and the clay and dirt washed from the soft wet phosphate. It contains from 50–60 per cent. tricalcium phosphate.

Tennessee blue rock phosphate is estimated at 40,000,000 tons, and contains from 60–78 per cent. tricalcium phosphate.

Tennessee white rock phosphate deposits are not large in extent, and give 80–90 per cent. tricalcium phosphate.

South Carolina phosphate, which is also called Charleston phosphate, is found on land and in river beds, and is classed as land or river phosphate. It contains from 50–60 per cent. tricalcium phosphate.

South Carolina phosphate is suitable for the manufacture of superphosphate, and generally gives products containing from 24–30 per cent. soluble phosphate.

Utah, Idaho, and Wyoming contain large deposits of

phosphate rock. Canadian phosphorite contains from 70–90 per cent. tricalcium phosphate.

Extensive deposits of mineral phosphates are found on several of the South Sea Islands, and Ocean and Pleasant Island deposits are estimated at 50,000,000 tons.

Christmas Island and the Islands of Makatea, Matahiva, and Niau also yield phosphates containing from 73–80 per cent. tricalcium phosphate.

Caribbean phosphates are important ones, some of which are classed as phosphatic guanos.

Aruba phosphate contains from 75–80 per cent. tricalcium phosphate.

Monk's Island phosphates yield 70 per cent. of the phosphate.

Curaçao phosphate contains 85 per cent. tricalcium phosphate, which makes a superphosphate with 44–45 per cent. soluble phosphate.

Sombrero and Navassa phosphates contain from 70–78 and 60–70 per cent. tricalcium phosphate respectively.

Redonda phosphate deposits consist chiefly of aluminium phosphate, and are unsuitable for making superphosphate or for use in the raw state. They contain 38 per cent. phosphoric acid, and from 33–35 per cent. aluminium and iron oxides.

Estremandura phosphorite is a fluor-apatite mixed with quartz and chalk. It is usually divided into three qualities containing 50, 60, and 70 per cent. tricalcium phosphate respectively.

African phosphates are known as Algerian, Tunisian, Gasfa, and Egyptian phosphates. They are soft, powdery minerals containing calcium carbonate. Large deposits are found in Tunis and Algeria. The Gasfa phosphate contains from 55–65 per cent. tricalcium phosphate.

Safaga and Kossier on the Red Sea, and Sebaia on the Nile have deposits which, when concentrated, contain from 60–70 per cent. tricalcium phosphate.

South Africa yields low-grade deposits north of Cape Town.

Belgian and Somme phosphates consist of phosphate rock containing from 20–30 per cent. calcium phosphate with chalk, also pockets of richer material with a tricalcium phosphate content of from 50–80 per cent. This is known as Somme phosphate.

Belgian phosphates are generally of low quality, the washed material containing from 40–45 per cent. of calcium phosphate. They are used as diluents for other phosphates.

Pas de Calais phosphate contains from 45–50 per cent. calcium phosphate.

Norwegian apatite yields 86 per cent. calcium phosphate, and Bohemian phosphate contains 33 per cent. phosphate.

Rock phosphates are ground in a crusher, and then in a ball mill. They are used in the manufacture of superphosphate, and are now frequently employed in the raw state as fertilisers.

The finely ground minerals are considerably used in America, where they are very popular, and a series of field trials have shown them to be of great value.

They are specially valuable when very finely ground, and may under certain circumstances give as good results as basic slag, although generally somewhat slower in their action.

As they are cheaper per unit of phosphate this is important, for the amount necessary is from 5–6 cwts. per acre, which is equivalent to 10 cwts. of basic slag.

It is stated that Rhenania and Vesta phosphates have been shown to give as good results as those obtained with

superphosphate or basic slag. These phosphates are prepared by sintering together phosphate rock, limestone, and alkali silicate at 1200–1300° C. in an electric furnace. The resulting product approximates to the formula, $Ca_2KNa(PO_4)_2$.

It is impossible to emphasise too much the necessity of using the very finely ground material.

Application.—A series of pot experiments, using phosphates as fertilisers, have given the following relative figures :—

No phosphate	100
Basic slag..	389
Florida acid phosphate	363–372
Raw ground phosphate	363
Dicalcium phosphate	348
Colloid ground phosphate	324

Trials at Cockle Park on grass have shown that North African ground rock phosphate is comparable with high-grade basic slag. Mineral phosphates appear to give the best results on heavy clay lands and lands in wet districts. It is stated that lime tends to retard the action of these phosphates.

The form in which phosphoric acid occurs is the same as in bones, that is, tricalcium phosphate.

Ground rock phosphates contain on an average from 55–85 per cent. calcium phosphate. Many contain much less than this and a few more.

A quality is sold with a guarantee of 58 per cent. calcium phosphate, having the same fineness as is guaranteed with basic slag, that is, that 80 per cent. will pass through a 100-mesh sieve. It is also produced that 80 per cent. of it will pass through a 120-mesh sieve.

A mixture of mineral phosphate and superphosphate affords help to young plants, and has given equal results as superphosphate in the cases of mangolds, potatoes, and hay.

Phosphatic guanos.—These materials usually consist of deposits of guano which have been rain-washed, so that the whole of their soluble constituents containing the nitrogen have been leached out, leaving the insoluble matter behind, which mainly consists of calcium phosphate. The amount varies from 25–90 per cent. calcium phosphate. Some samples still contain appreciable amounts of nitrogen, but usually they are only valuable for their phosphate content.

They are found in various islands in the West Indies and Pacific Ocean. Gypsum is present in some deposits to a considerable extent. They have much value as fertilising materials, but are usually used for the manufacture of good superphosphate.

Superphosphate.—By far the most widely used of all artificial fertilisers, this valuable material is generally made from mineral phosphates, by acting upon them with sulphuric acid. The phosphate is finely ground before treatment with the acid, and calcium sulphate and free phosphoric acid are first formed.

$$3Ca_3(PO_4)_2+6H_2SO_4+12H_2O \\ =4H_3PO_4+Ca_3(PO_4)_2+6CaSO_4.2H_2O.$$

The phosphoric acid reacts with the remaining phosphate to produce the more soluble compound, $CaH_4P_2O_8$.

$$4H_3PO_4+Ca_3(PO_4)_2+3H_2O=3CaH_4P_2O_8H_2O.$$

The combined reactions can be represented as follows :—

$$Ca_3(PO_4)_2+2H_2SO_4+5H_2O \\ =CaH_4P_2O_8.2H_2O+2CaSO_4.H_2O.$$

The acid also acts upon the calcium carbonate, calcium chloride, calcium fluoride, and oxides of iron and aluminium which may be present.

In the process of manufacture, the phosphate and the acid are weighed before mixing, and air is drawn through after mixing to remove poisonous gases which are produced.

If insufficient sulphuric acid is used, the dicalcium salt $Ca_2H_2(PO_4)_2$ is formed, and if excess of acid, complete decomposition takes place of the calcium salt, with the production of free phosphoric acid and gypsum.

Calcium fluoride is present in nearly all mineral phosphates, and is objectionable in that it produces hydrofluoric acid, this reacting with the silica to form silicon hydride, SiH_4, and finally hydrofluosilicic acid, H_2SiF_6.

The carbonates present react with the acid to give carbon dioxide and calcium sulphate. This is an advantage as the carbon dioxide lightens the mass when it is evolved.

Aluminium and iron oxides are objectionable constituents, as they tend to cause the reversion of the soluble phosphate to the insoluble form.

On an average 10 tons of mineral phosphate will produce 18 tons of superphosphate.

Superphosphate consists of mono-calcium phosphate, $CaH_4P_2O_8$, gypsum, $CaSO_4.2H_2O$, and generally some tricalcium phosphate, $Ca_3P_2O_8$.

In some samples iron and aluminium sulphates are also present. The most important constituent is the mono-calcium phosphate, which is soluble in water, the tricalcium phosphate, which is insoluble in water, being of less value.

Commerical superphosphates possessing the best mechanical properties for their distribution should not contain more than 12 per cent. of water and 2 per cent. free phosphoric acid, calculated as P_2O_5.

Superphosphate will keep well provided it does not contain more than 2 per cent. of the oxides of iron and aluminium, for mono-calcium phosphates react with the sulphates of aluminium and iron, causing a reversion to the dicalcium phosphate, which is insoluble in water, although it has fertilising properties.

The phosphate in a fertiliser may be either in an insoluble or soluble form, and as the value of these two types is widely different, they must be mentioned separately in an analysis. Soluble phosphate is the mono-calcium phosphate formed during the manufacture of superphosphate.

Sometimes the soluble phosphate is considered as the amount soluble in a 2 per cent. citric acid solution, but under the Fertilisers and Feeding Stuffs Act of 1906, if this is so, it must be stated on the invoice.

The water soluble part differs from the citric acid soluble phosphate in its rapidity of action in the soil, due to its being quickly distributed. The citric acid soluble form has, however, more immediate fertilising value than the insoluble phosphate. The citric acid soluble phosphate in superphosphate is considered to be about 70 per cent. as efficient as the water soluble phosphate.

It follows, therefore, that the true value is found by determining the portion soluble in water, and the amount of the insoluble phosphate which is soluble in a 2 per cent. citric acid solution. Reverted phosphoric acid is the dicalcium phosphate which is also formed in the process, and is soluble in the 2 per cent. citric acid solution.

The available phosphoric acid is the sum of the soluble and reverted forms, and both are suitable for fertilising purposes almost immediately.

Insoluble phosphate is tricalcium phosphate as it

exists in phosphate rock, and in this form is not directly available for plant food, but becomes so after a time.

Superphosphate is usually sold on the basis of what is termed its soluble phosphate. This means the quantity of tricalcium phosphate which has been rendered soluble. The phosphoric acid soluble in water is determined as P_2O_5, and calculated into its equivalent amount of tri-calcium phosphate by multiplying by 2·18, this being then called soluble phosphate.

A 25 per cent. soluble phosphate therefore contains the equivalent of 25 per cent. tricalcium phosphate. It does not contain, as is sometimes thought, 25 per cent. of material soluble in water.

On the Continent it is often calculated as P_2O_5 soluble in water. As 142 lb. of P_2O_5 is equal to 310 lb. of phosphate of lime, the percentage of calcium phosphate can be found by multiplying the percentage of P_2O_5 by 2·18.

It should be mentioned that the citric acid solubility of phosphate is not altogether a measure of its fertilising value, as many good results have been obtained from the use of raw insoluble phosphates.

In reference to the solubility of phosphates, some interesting experiments have been conducted with various phosphates and the amount of them taken up by the plant. It was found in these pot experiments that the intake of phosphorus by the plant was proportional to the solubility in a 2 per cent. citric acid solution, but this test had no value in the case of mineral phosphates. By using oxalic acid as the solvent, the results showed that with all phosphatic fertilisers a definite proportion of the total phosphate became soluble in this solvent, and the amount dissolved is independent of the weight of phosphate taken.

These solubility figures also indicate the rate of intake

of phosphorus by the plant when comparing slags with slags and mineral phosphates with mineral phosphates, and it would appear that this method is a satisfactory one for the determination of soluble phosphate in mineral phosphate.[1]

Superphosphate is still often considered an acid fertiliser, and that it increases the acidity of the soil, but evidence has shown that it has no acidifying action on the soil, but has beneficial action in precipitating the toxic aluminium compounds. Superphosphate is frequently called superphosphate of lime, and in consequence it is often thought that it contains actual lime, and the addition of the latter is not needed. Superphosphate contains no true lime, and is no substitute for lime in the soil. It contains from 25–38 per cent. of soluble phosphate, and is usually sold in three grades.

30 per cent. soluble phosphate = 13·6 per cent. P_2O_5.
33 per cent. soluble phosphate = 15·0 per cent. P_2O_5.
35 per cent. soluble phosphate = 16·0 per cent. P_2O_5.

The more concentrated grades save freight charges, but the others contain more gypsum, which under some circumstances has distinct value.

Application.—Superphosphate has two effects upon plant life; it favours root development in the early stages, and hastens maturity in the later stages.

It is most valuable for potatoes and root crops, and from 4–8 cwts. per acre are used for potatoes. It is especially useful for swedes and turnips, increasing the amount and quality of the crop. It also supplements the value of feeding fodder.

Superphosphate hastens the ripening of cereals, and for this reason is very useful in wet districts, 3 cwts. per

[1] E. Vanstone, *Journ. Soc. Chem. Ind.*, vol. 45, No. 13, 1926.

acre with $\frac{3}{4}$ cwt. ammonium sulphate being a suitable amount.

It also corrects rankness present on grounds which have grown roots for sheep fed on the land.

Mangolds do well with from 2–3 cwts. per acre, and in wet districts it has high value for this purpose.

The addition of superphosphate to the nitrogenous dressing for corn crops helps to give hard growth and prevent or cure too sappy a growth in the straw.

Superphosphate, although it is soluble in water, does not wash out, as it is rapidly precipitated in the soil.

Dry sandy soils respond less than heavy land to this fertiliser, and its application to the latter type will in many cases improve its texture.

Double superphosphate.—A concentrated fertiliser, which is essentially a mono-calcium phosphate, $CaH_4(PO_4)_2$, made mainly in America and Germany, by first preparing free phosphoric acid from mineral phosphate by means of sulphuric acid, getting rid of the calcium sulphate by precipitation. Mineral phosphate is now added to the concentrated solution in such quantity as to make the mono-calcium phosphate or double phosphate. The product is then dried and finely powdered.

Somme phosphate and South Carolina phosphate are the usual mineral phosphates used.

The reversion of this material takes place if impurities such as iron or aluminium oxides are present, and unconverted tricalcium phosphate also causes some reversion to insoluble phosphate. Storing in heaps is likely to cause a change to the insoluble condition.

Double superphosphate on an average contains about 48 per cent. of total phosphate, and 43 per cent. of water soluble phosphate.

Basic superphosphate.—A product obtained by adding 85 per cent. of superphosphate to 15 per cent. of slaked lime, mixing, and allowing the mixture to stand.

The phosphate is rendered insoluble in water, but it is soluble in a weak citric acid solution, and it is dissolved out in the soil by the soil water.

The material is in the form of a bulky dry powder, and is easily distributed. It has considerable value on soils deficient in lime.

Tetraphosphate of lime.—A fertiliser made by heating finely ground natural phosphate with 5 per cent. of a mixture of calcium, magnesium, and sodium carbonates to a temperature of 650° C.

The calcined mass is moistened and earth or sand added, until the phosphate content is about 40 per cent. tricalcium phosphate. It is stated to be a satisfactory fertiliser, and is of value on land lacking in lime.

Tetraphosphate is considered as being only 38 per cent. as efficient as superphosphate.

Precipitated phosphate.—Phosphatic minerals which are unsuitable for making superphosphate because of their low phosphate content, or the presence of harmful constituents such as iron and aluminium oxides, are sometimes treated with acid, whereby the calcium phosphate is dissolved out, and then recovered by precipitation.

If a base is added until the solution is just acid, dicalcium phosphate is the chief product.

It is a concentrated fertiliser, and may contain as much as 40 per cent. P_2O_5, in a condition next in value to the mono-calcium phosphate.

Precipitated bone flour.—A fertiliser obtained by the treatment of bones with hydrochloric acid. It is a by-product in the manufacture of glue and gelatin.

The bones are freed from fat by solvents, and then treated with the acid, the whole of the phosphate being dissolved and the gelatin left. The solution of phosphoric acid is neutralised with milk of lime and the phosphate precipitated as a mixture of di- and tricalcium phosphates. It is filtered and washed in a filter press, and the cakes dried. They contain from 30–40 per cent. phosphoric acid, P_2O_5. It appears to be a mixture of equal parts of di- and tricalcium phosphates, and is easily soluble in dilute citric acid solution.

It is stated to be an excellent fertiliser for turnips.

Basic slag.—A by-product in the manufacture of steel from pig iron rich in phosphorus. The pig iron contains phosphorus, silicon, carbon, sulphur, and other substances, which are removed from it by heating the molten metal in the presence of air when they are oxidised. The slag contains phosphorus equivalent to about 40 per cent. tricalcium phosphate.

The older Bessemer process for steel consists in blowing air through the molten pig iron in the Bessemer converter, but this method has been modified by Thomas and Gilchrist by lining the furnace with lime and magnesia, adding lime, and applying the air blast to the molten mixture.

The phosphorus in the pig iron is oxidised by the air, and the product combines with the lime and magnesia to form the slag. The slag contains from 40–50 per cent. of lime, varying quantities of magnesia, aluminium oxide, iron oxide, oxide of manganese, silica, and phosphoric acid equivalent to from 20–50 per cent. tricalcium phosphate.

A more recent process for the manufacture of steel is the open-hearth process, but it produces a lower-grade slag, in that the amount of phosphorus is low, and that present

is of lower citric acid solubility, owing to the use of calcium fluoride to make the mass more fusible in the process. This method yields a slag containing from 15–31 per cent. tricalcium phosphate.

There are three classes of basic slag: (1) Bessemer slag, containing phosphoric acid equivalent to 41–43 per cent. tricalcium phosphate, and largely soluble, about 80 per cent. dissolving in a 2 per cent. citric acid solution. This grade is not now produced in large quantities. (2) Basic open-hearth slag, containing phosphoric acid equivalent to 15–31 per cent. tricalcium phosphate, of which 80 per cent. is soluble in 2 per cent. citric acid. It is a commercial grade described as low-grade high soluble slag. The phosphorus in this slag has the same agricultural value as that in Bessemer slag. (3) The present-day basic open-hearth slag, made by the use of lime and fluorspar and sometimes called fluorspar slag. It is described as low-grade low-soluble slag, and contains 15–20 per cent. tricalcium phosphate, but less than 20 per cent. of it is soluble in a 2 per cent. citric acid solution. The phosphorus in this slag is said to be in the form of a double salt of tricalcium phosphate and calcium silicate, and also as a basic iron phosphate.

Basic slag is not soluble in water, but is dissolved by carbonic acid, which occurs in soil water, and fineness of division hastens this solution.

Slag is sold on its basis of total phosphate, but it pays to use a high soluble slag on most crops, although a less soluble one is suitable for grass.

The solubility is determined by the amount which will dissolve in a 2 per cent. citric acid solution, and a good sample should contain 30 per cent. total phosphate, of which 80 per cent. is soluble in 2 per cent. citric acid.

The lime in slag is in combination with phosphate and silicate, and is valuable on certain soils.

Attempts have been made from time to time to improve slag for fertilising purposes, but practically the only process is grinding the product. The blocks of slag are broken up, and after freeing from metal, are ground in a ball mill in an air draught. so that the finished article contains from 80–90 per cent. which will pass through a 100-mesh sieve.

Basic slag has been so successful as a fertiliser that several artificial products have been made and sold. These have been prepared by heating mineral phosphates with sand, chalk, and other material, and grinding. Such an article is Wiborgh phosphate, a German production, which is made by heating mineral phosphate with soda ash. The product consists mainly of a calcium tetraphosphate, and 95 per cent. of it is stated to be soluble in citric acid solution. It contains 27 per cent. phosphoric acid, P_2O_5, and 38 per cent. of lime.

Another product, known as artificial Thomas phosphate meal, contains from 15–17 per cent. P_2O_5, and 41 per cent. lime. Of the phosphate, 97 per cent. is stated to be soluble in dilute citric acid.

Application.—In its application slag is not so soluble as superphosphate, but it contains more lime. It gives the best results when applied to poor pasture on heavy clay, but has given good returns on lighter soils. It is used in wet districts on arable land, and preference is given to basic slag on soils which are sour, and it is valuable on moorland rich in organic matter and in clay, but deficient in lime. The usual slag contains from 3–5 per cent. of free lime, which has value on soils requiring this substance.

In some cases basic slag has given as good results as

superphosphate, and in the case of poor grass land has proved better in certain circumstances.

It is best applied in the spring, but on grass can be put on at any time. For the latter purpose, from 8–10 cwts. per acre are used for the first dressing and 5 cwts. for the second dressing.

When clover is checked by grasses, slag will improve the land, and the increase in the growth of white clover is one of the most marked benefits of the application of this fertiliser.

It is important that potash be present in the soil to obtain the best results from basic slag.

In view of the fact that experiments have shown that manganese plays some part in plant life, it should be mentioned that many slags contain this material.

Basic slag has given good results with leguminous crops and turnips, especially if finger and toe disease is prevalent in the latter.

Phosphor manganese.—A fertilising material which is usually produced from a mineral phosphate, manganiferous slag from the spiegeleisen process, and a basic oxidising agent such as pyrolusite, in the electric furnace.

It is a type of basic slag, but differs in its higher phosphorus and manganese content. The phosphoric acid is insoluble in dilute citric acid.

It contains the equivalent of 42·5 per cent. calcium phosphate, lime, magnesia, silica, alumina, ferric oxide, and about 8 per cent. of oxide of manganese.

It is stated that fertilising experiments with this material have shown it to be superior to superphosphate in the cultivation of leguminous crops, oats, wheat, and maize, and it has given good results with sugar beet.

Steamed bone flour.—Although this fertiliser contains

about 1 per cent. of nitrogen it is regarded as a purely phosphatic material. It generally contains from 60–70 per cent. of calcium phosphate, but in some cases the nitrogen amounts to 2 per cent., and the phosphate to 55 per cent. A commercial sample gave the following values upon analysis: organic matter 10 per cent. (nitrogen 0·9 per cent.), calcium phosphate 66 per cent. (P_2O_5 30 per cent.).

The usual quality has nearly all its nitrogen removed in the steaming process, and in consequence the material can be very finely ground.

It is more rapid in its action than raw bone meal (which is considered under the nitrogen-phosphatic fertilisers), but it is important that, like many other phosphatic materials, it should be finely ground.

Application.—Steamed bone flour has been found useful for dry situations, but it is rarely better than superphosphate for turnips, or basic slag for grass.

It has an advantage over bone meal, in that it is usually more finely ground, and therefore more easily distributed.

Bone ash.—This material is usually imported from South America. In this article all the organic matter has been destroyed, and it is high in its content of tricalcium phosphate, normally containing from 73–75 per cent. of this substance.

Bone black.—Calcined bones are used by sugar refiners to decolorise sugar juices. The bone black consists of about 10 per cent. finely divided carbon mixed with mineral constituents of bone, and often contains from 75–80 per cent. of calcium phosphate. It is made by heating bones in closed retorts.

After its use in sugar refining, the material is sold for fertilising purposes under the name of spent char. It

contains small amounts of nitrogen, usually from 1·5–2 per cent., and is rich in phosphoric acid, containing from 30–35 per cent. P_2O_5, equivalent to 65–76 per cent. of tricalcium phosphate.

The phosphoric acid is not readily available without treatment with acid. Superphosphate and dissolved bone black are terms used for bone meal and bone black which have been treated with acid to render the phosphoric acid more available.

Sulphite waste liquors.—Sulphite waste liquors treated with material containing phosphate, evaporated, and burnt to render the phosphate available have also been prepared for use as phosphatic fertilisers.

Relative value of phosphatic fertilisers.—Superphosphate being mainly in a soluble form is rapidly diffused through the soil, and is therefore more speedy in its action than basic slag or mineral phosphate. For roots, potatoes, hops, and short season crops, superphosphate is usually the best one to apply, and it does well on good soils. With the poorer types of soil, and on heavy clay or land deficient in lime, basic slag or steamed bone flour is better. Where soils are known to be poor in lime superphosphate does not appear to be so good, and basic slag would be more beneficial.

The value of superphosphate and basic slag are nearly equal, and the choice will depend upon special circumstances, such as the climate and the type of soil. Generally, however, superphosphate is better for arable land, and basic slag best for grass.

The conditions which appear suitable for the assimilation of ground rock phosphate is the presence of humus and a low lime content. The availability of phosphates depends upon a variety of different factors, including the

nature of the soil and the particular crop grown. In most districts, and on sour soils, mineral phosphate is often equal to high-grade basic slag, especially for meadow grass and turnips, and on good soil is often only a little inferior to basic slag.

Chalk soils appear to be unsuitable for the application of insoluble phosphates.

CHAPTER V

POTASSIC FERTILISERS

POTASH is more widely distributed in soils than are nitrogen and phosphoric acid, and ordinary soils usually contain supplies of potash in an insoluble condition, which can be made available by the application of salt or sulphate of soda, or by liming the land. For certain crops it is safer to use lime than other materials, although mangolds have benefited considerably by the addition of salt.

When the salts of potash are added to the soil, the base is absorbed and not washed out, freeing the acid radicle which attacks the lime or other bases in the soil. The potash is retained, and calcium sulphate, calcium nitrate, and calcium chloride appear in the drainage water.

The presence of potash in the soil increases the availability of phosphate, and it is also intimately connected with assimilation of carbon by the green leaves and stems of plants, and the production of starch and sugar is stimulated by the action of potash. It appears that it must be in the soil to a considerable extent before it can be assimilated by the plant, and therefore, there is little danger of adding too much.

Potash especially improves the size and weight of roots, seeds, and fruits, and is essential in the cultivation of sugar-producing plants, especially potatoes, mangolds, tomatoes, and sugar beet. It is important in barley cultivation.

It stiffens the straw of cereal crops, and imparts vigour to plants, helping them to resist disease and bad weather.

Leguminous crops and grass land benefit by the application of potash. It is specially valuable on light sand or thin chalk soils, potatoes and cereals on such soils being particularly helped.

The colour of the leaf is an indication of the potash supply, and poorly nourished leaves lose their natural green tint.

With potatoes suffering from leaf roll, the disease is minimised by the use of potash, and an increase of potash sometimes diminishes potato scab.

Potash fertilisers.—Originally all potash salts for the production of fertilisers came from the Stassfurt deposits in Germany, but more recently, natural deposits in Alsace, Spain, and America have been investigated. As another source, the Dead Sea must be mentioned, for this sea is estimated to contain 2,000,000,000 metric tons of potassium chloride, in addition to large quantities of sodium chloride, calcium chloride, and magnesium chloride.

Poland has also come to the front in the production of potash. This country has two mines, and the total production during the first half of 1926 amounted to 99,599 tons, of which 35,283 tons were kainit, and 64,316 tons sylvinite. These deposits are not refined, but only ground, and it is estimated that if the production and use of potash in Poland was as intensive as in Germany, this country would be able to account for 2,000,000 tons per annum. Germany's production has become so intensive that it greatly exceeds the calculated increased consumption. Of the world's consumption in the year 1925, about 76·5 per cent. was supplied by Germany, 20 per cent. by

France, 2 per cent. by the United States, and 1·5 per cent. by Poland.

During the first six months of 1926, the sales of potash in Germany were 15 per cent. lower than those of the corresponding period of 1925, whilst the French products advanced by 20 per cent. for the same time.

The Alsatian deposits are estimated to contain 300 million tons of potash salts, containing 22 per cent. potash.

The Stassfurt deposits consist of several compounds overlying the beds of rock salt. The chief ones used as fertilisers are kainit, a potassium magnesium sulphate and magnesium chloride, with rock salt; sylvinite, a mixture of sylvine (potassium chloride), rock salt, and kainit; and carnallite, $MgCl_2.KCl$, mixed with rock salt.

Potash manure salts.—The crude potash salts of commerce are obtained from these deposits, and fertilisers containing 20, 30, or 40 per cent. potash are made or blended. They consist of natural sylvinite, kainit, potassium chloride, carnallite, and schoenite, and vary greatly in colour and appearance. One 30 per cent. potash salt contained 48 per cent. potassium chloride and 27 per cent. sodium chloride.

Potassium sulphate fertilisers are hardest to produce and are consequently dearer. The ordinary ones contain potassium chloride. The principal potash fertilisers are French kainit, consisting of sylvinite, a mixture of potassium chloride, sodium chloride and kainit, and containing 14 per cent. potash; French extra kainit, containing from 22–24 per cent. of potash; French potash manure salts, containing 30 and 40 per cent. of potash; German kainit, consisting of lime, magnesia, sulphates, from 25–35 per cent. sodium chloride and 12·5 per cent. potash, and German potash manure salts containing 20 and 30 per cent. potash.

The pure salts of potassium are sometimes made from these potash minerals, and potassium chloride is usually obtained from sylvine by cooling a saturated solution of it, when potassium chloride crystallises out. Potassium chloride is also produced from crude carnallite which contains potassium chloride, magnesium chloride, sodium chloride, and magnesium sulphate, with the potassium salt to the extent of 16 per cent. The material is dissolved rapidly in the washing from the first products and other liquors, clarified, and crystallised to obtain crude potassium chloride containing some sodium chloride and magnesium chloride. This product is washed at a low temperature to finally obtain a salt containing from 80–98 per cent. potassium chloride.

Leucite.—This mineral is an aluminium-potassium silicate found in Italy in volcanic rocks. It is sometimes ground up and used directly as a fertiliser, and this method has given good results with rice.

A Danish patent recommends the grinding up of the leucite or other mineral with suitable amounts of chalk or lime.

More usually leucite is treated to either obtain a potassium salt or to render the potash more available. One method consists in separating the pure leucite from the rock by magnetic separation which gives about 98 per cent. leucite. This is attacked with hydrochloric acid when potassium and aluminium pass into solution as chloride. The potassium salt is obtained by passing hydrochloric acid gas into the solution, when potassium chloride of 99 per cent. purity is finally obtained.

Alunite.—This mineral is a double silicate of aluminium and potassium, which after ignition and leaching with

water, can be made to yield a potassium sulphate of 90 per cent. purity.

Certain potash minerals containing acid soluble potash, are stated to have some of their potash made soluble by grinding and treating with urea salts.

Greensand.—This New Jersey mineral has been made to produce potash fertilisers by a new process which consists in treating it with sulphuric acid to convert the iron, aluminium, and potassium into sulphates. The solution may then be crystallised, the iron converted into insoluble iron oxide by calcining, the aluminium into insoluble aluminium oxide by still further heating, and the potassium sulphate leached out with water.

Potassium sulphate from kainit.—The sulphate is generally made from kainit, or by acting upon potassium chloride with sulphuric acid.

A saturated solution of kainit is allowed to crystallise, when potassium magnesium sulphate comes out of solution, or a mixture of kainit and sylvinite is treated with a hot solution of kainit and cooled to produce the same salt. This is sometimes used directly as a fertiliser. To produce potassium sulphate from the salt, a hot saturated solution of it is run on to dry powdered potassium chloride, when potassium sulphate is produced in crystals, and separated at a low temperature in a centrifuge.

Potassium sulphate from cement manufacture.—When fluorspar is added to the clays and shales used in the manufacture of cement, the potash is volatilised in the cement kiln as potassium fluoride. The sulphur in the fuel produces sulphuric acid, which reacts with this substance giving potassium sulphate and calcium fluoride. Washing with water dissolves out most of the potassium sulphate, and it is recovered as such.

Commercial forms of sulphate of potash have varying degrees of purity, from 25–50 per cent. potash, and the chloride usually contains about 50 per cent. potash.

Potassium salts from sea water.—By a new Italian method for which Dr. Niccoli is responsible, potassium salts are obtained from the sea water contained in two salt lakes in Tripoli. Solar heat only is used and the potassium sulphate obtained by treatment with schoenite and potassium chloride, and separated in boiling water. A potassium sulphate containing about 95 per cent. is obtained, but the commercial article contains 90 per cent. Magnesium chloride and sulphate are by-products.

Potash from spent molasses liquor.—The spent liquor is burnt after it has been concentrated, to produce a charcoal. The waste charcoal contains 8 per cent. and over of potash, generally as carbonate, and is suitable for use as a fertiliser.

Comparison of chloride and sulphate.—Except in the case of mangolds, there are few occasions when chlorides are needed in any quantity, and as sodium chloride is fed to cattle and returned in manure, it is not so necessary. Some crops, such as potatoes, are adversely affected by sodium chloride, whereas sulphur contained in the sulphate is an important constituent of plants. For these reasons it would appear that the sulphate is to be preferred to the chloride.

Wood and plant ashes.—The ashes of hedge trimmings contain up to 10 per cent. of potash. The ashes of young wood have a potash content as high as 35 per cent., but the old wood only up to 15 per cent. potash. Brushwood, fallen timber, and other waste materials yield ash containing from 5–8 per cent. potash and 20–40 per cent. of lime. Burnt hayricks, and the dust obtained during

threshing, yields an ash containing up to 10 per cent. potash.

The ash from young bracken plants gives a potash content of from 51–54 per cent., and the older plants yield one with from 21–29 per cent. potash.

According to G. N. Blackshaw, the ash from 16 samples of different woods gave the following amounts of potash and other materials: from 0·41–5·22 per cent. potash, 0·88–5·56 per cent. phosphoric acid, and 18·77–49·33 per cent. of lime.

Sunflower ash, obtained from burned leaves, stalks, and heads, contained 20·9 per cent. of potash, 0·98 per cent. of phosphoric acid, and 12 per cent. of lime.

Maize cobs ash, which amounted to 0·98 per cent., gave 36·3 per cent. of potash and 4·6 per cent. of phosphoric acid.

Leaf mould ash contains 0·41 per cent. of potash, 0·75 per cent. of phosphoric acid, and 9·68 per cent. of lime.

Peat ash from burned reeds, grass roots, and leaves which had been weathered for five years contained 0·24 per cent. of potash, 0·22 per cent. of phosphoric acid, and 4·39 per cent. of lime.[1]

The potash in these ashes is in a highly available form, mainly as carbonate, and should not be allowed to remain in the open, for rain will wash out most of the potash. The ash also tends to absorb moisture from the air, and should either be used immediately or mixed with superphosphate.

Banana refuse.—The stems of this plant contain a considerable amount of potash, and the ash of them can provide a suitable source of this fertiliser.

Flue dust.—A valuable by-product of the iron industry is blast furnace dust, since it contains potash.

[1] *Rhodesia Agri. Journ.* 1927, xx, pp. 47–50.

In the process, iron ore, limestone, and coke are heated in a furnace provided with an air blast. Such a high temperature is reached that the potassium compounds are volatilised and are carried into the flues and there deposited. The flue gases are washed with water in some cases.

The potash content of the dust is very variable, and coke-fed furnaces furnish larger amounts of potash than do the coal-fed ones. Attempts to raise the quantity of potash by the addition of small amounts of sodium chloride to increase the volatilisation of the potash are most promising.

Blast furnace dust can be used directly as a fertiliser, or worked up for potassium salts. It is a very good source of potassium chloride, which is easily recovered from the dust, especially if salt has been used in its production, thereby converting most of the potash into the chloride. The dust is washed with water and the solution crystallised.

The flue dust from the blast furnace contains potassium compounds derived from the potash volatilised from the fuel, ore, and flux, and is usually divided into three grades: (1) The black dust from the main collectors, which contains soot and about 3 per cent. of potash as sulphate, (2) a red or whitish-brown dust collected from the boilers which is derived from the black dust by burning away most of the soot. It contains 15 per cent. of potash as the sulphate or silicate, and (3) an intermediate product.

Some samples contain cyanides and sulphocyanides, which are harmful to plants if present in large quantities.

The dust is sometimes lixiviated and made into the chloride or sulphate of potash.

Wool wash.—Potash is an important by-product of the wool-combing industry. Raw wool is sometimes

washed with hot very weak alkali, but it is more often extracted with cold water, the solution evaporated, and heated. In a more recent process the wash liquor is concentrated and extracted with benzine to free it from fatty matter, the solution evaporated to a dry cake containing about 20 per cent. potash, and the material used as a fertiliser.

Application of potassic fertilisers.—Kainit, sylvinite, and potash salts are particularly suitable for use in the cultivation of mangolds, because of the sodium chloride they contain, and the application of salt has greatly benefited this crop. Therefore, any land known to give good yields with kainit should have an application of salt.

From 4–6 cwts. per acre are suitable quantities of a potash fertiliser to apply if no farmyard manure has been given. The latter is rich in potash, and reduces the need for potash fertilisers.

For potatoes, the sulphate is to be preferred to the chloride, and from 1–2 cwts. per acre are suitable quantities if no farmyard manure has been applied. For cereals on light land, land after a straw crop, and land poor in potash, 57 lb. potassium chloride or sulphate, or 100 lb. 30 per cent. potash salts, or 140 lb. 20 per cent. potash salts, or 2 cwts. kainit or sylvinite, should be applied as part of the general dressing of fertilisers.

Leguminous, root, and leaf crops require from 100–200 lb. of potassium chloride or sulphate, or proportionally greater amounts of potash salts or kainit.

Grass land does well with from 60–75 lb. of potassium chloride, or proportionally more of potash salts or kainit.

For the cultivation of fruit and tomatoes, it is important to have potash present, and the green patch on tomatoes

is probably due to a deficiency of potash. The leaf scorch of fruit trees is stated to result from the same cause.

In the application of potassic fertilisers, it may be stated that generally it is better to use the sulphate in preference to the chloride, and concentrated salts rather than kainit or potash salts.

CHAPTER VI

NITROGENOUS-PHOSPHATIC FERTILISERS

UNDER this heading are considered the following materials, as they contain both nitrogen and phosphorus in sufficient amount to recognise them as nitrogenous-phosphatic plant foods: Bones, bone meal, dissolved bones or vitriolised bones, mixed superphosphate, meat guano or meat meal, tank water from slaughter-house tankage, fish manure or fish guano, Bombay cotton-cake, ammoniated superphosphate, bone compound fertilisers, Rhenania nitrogen-phosphate, phosphatic peat, phosphatic nitrate, Diammonphos, Ammonphos or ammonium phosphate, and Leunaphos.

Bones.—The bone fertilisers are usually considered as phosphatic fertilisers only, and in the case of steamed bone flour, with a low nitrogen content (usually 1 per cent.), rightly so, but bones themselves, and the meal obtained from them, often contain sufficient nitrogen to have some value as nitrogenous fertilisers, as well as phosphatic ones.

Bones are one of the earliest fertilisers and were originally sold after being ground up only, when they contained fat which delayed their decomposition in the soil. They are now seldom used in the raw state, but are usually steamed to extract fat, or solvent extracted, or are boiled under pressure to extract the greater part of their gelatinous matter.

The bones as supplied to the factories for the manufacture of fertilisers usually contain about 18 per cent. nitrogenous material and 44 per cent. of calcium phosphate. They are sorted and crushed to about 1-in. pieces. They are then extracted with a hot solvent, often benzine, to take out the fat, and remove some water. The fat and water are run off. In some works the bones are treated with dilute sulphuric acid, boiled, and steam admitted, when the fat and gelatin are removed. The bones are then easily ground very finely. The solvent extracted material gives a better bone meal. The mineral matter in bone is stated to be present as oxy-apatite, $3Ca_3P_2O_8.CaO$, or hydroxy-apatite, $3Ca_3P_2O_8.Ca(OH)_2$.

Bone meal.—Those bones which have been merely degreased are still rich in organic matter and are generally marketed as a coarse meal containing about 35 per cent. of organic matter with a nitrogen content of 3·5–4·5 per cent. and calcium phosphate amounting to about 45–50 per cent.

A better quality which has been degreased and partly deprived of its gelatinous material grinds more easily and is therefore quicker acting and more easily distributed. It contains from 3–5 per cent. nitrogen, and about 50 per cent. calcium phosphate, and is free from grease.

Application.—Bone meal has been found useful in the place of superphosphate for potatoes, and has given good results with these and other crops. It is safer, but not usually so effective as superphosphate for turnips, or basic slag for grass.

Bone meal usually acts best on a soil rich in humus or lacking in lime. It is not so satisfactory on calcareous soils.

Dissolved or vitriolised bones.—These are bones which have been treated with sulphuric acid to obtain the phosphate in a more soluble form. They are degreased and finely crushed, and mixed with sufficient sulphuric acid to dissolve about half the phosphate. After the reaction, the water is driven off by drying. A good dissolved bone should contain 2·5–3·5 per cent. nitrogen, 15–17 per cent. soluble phosphate, and 15–17 per cent. insoluble phosphate. The composition, however, varies greatly, and the condition is not usually so good as superphosphate, as they are often dark and lumpy. They are usually more expensive than superphosphate, and are not considered so good as this material.

Mixed superphosphates.—A fertiliser prepared by acting upon a mixture of mineral phosphate, bones, and some concentrated nitrogenous matter, with sulphuric acid. They are called "dissolved bone compounds," and should not be confused with dissolved bone which is obtained by using bones only.

Meat guano or meat meal.—This material is usually prepared in the Argentine from the tankage, which is a mixture of various refuse materials from slaughter-houses, such as blood, hair, scraps of meat, hide, and bone.

Most of the commercial meat meals are made during the process of the manufacture of extract of meat, and are mixtures of meat and bone. These products are exported from New Zealand and South America. The material is heated by steam or cooked to extract the fat, the liquid and fat being removed, and the material pressed to free it from most of its water. The cakes formed are broken up, dried, separated from any foreign matter such as iron, and finely ground. As considerable amounts

of grease are still left, it is sometimes treated with a solvent such as benzine, the solvent recovered, and the material dried. The tank water from the tankage after the grease is removed, is evaporated, and mixed with tankage to make a more concentrated product.

The composition varies as the amount of bone ground up with the meat. Nitrogenous samples contain from 11–13 per cent. of nitrogen and 1·3–6·6 per cent. of calcium phosphate, and phosphatic samples from 6–7 per cent. of nitrogen, and 31–37 per cent. of calcium phosphate.

Fray Bentos guano is a type of meat guano manufactured, and contains 6 per cent. of nitrogen and from 10–20 per cent. of calcium phosphate, and a usual quality contains 7 per cent. of nitrogen and 20 per cent. of calcium phosphate.

A German product made by drying the carcases of animals which have died from disease, and called flesh guano, contains 9·7 per cent. of nitrogen and 17·7 per cent. of calcium phosphate.

Meat meal has considerable value on light soils, and can be applied in December and January. It also improves the tilth.

Fish manure or fish guano.—Whole fish are employed as a fertilising material at places near the sea. Sprats contain about 64 per cent. of water and 2 per cent. of nitrogen, and give an ash containing 0·42 per cent. of potash, and 0·9 per cent. of phosphoric acid.

In British Columbia, it is now legal to use the abundant supply of pilchards for the manufacture of fertiliser, in addition to the preparation of fish meal and oil, and in consequence several plants have been erected to produce this product.

Fish manure or guano is usually made from various

kinds of fish refuse, and the refuse, with the offal and worthless fish is first cooked and the oil extracted by heat and pressure, or cooked, a current of air passed into the partially dry material, and then extracted with benzine. The benzine is run off, and that remaining in the mass distilled off by steam. The dried and extracted fish manure is ground up and usually contains from 8–10 per cent. of nitrogen, 8–20 per cent. of calcium phosphate, and 1 per cent. of potash. Some varieties contain less phosphate.

Several types of fish are used for the manufacture of these fertilisers. The Norwegian fish guano is made from cod, and often contains 8 per cent. of water, 7–9 per cent. of nitrogen, and 15–22 per cent. of calcium phosphate.

Herrings, sprats, menhadden, and other fish are also used.

Newfoundland cod refuse contains 5 per cent. of nitrogen and 40 per cent. of phosphate.

In Brittany, a similar product is obtained containing from 6–7 per cent. of nitrogen, and 29–39 per cent. of phosphate.

The menhadden guano contains 10 per cent. of water, 9 per cent. of nitrogen, and 10 per cent. of oil.

The usual composition of American fish guano is 9 per cent. of nitrogen, 15 per cent. of phosphate, and 7 per cent. of oil.

Some fish refuse contains 50 per cent. of water, 3 per cent. of nitrogen, 4 per cent. of calcium phosphate, and oil up to 15 per cent.

The fish offal of towns is often simply dried and ground. Its principal value is its nitrogen, which varies from 6–11 per cent., and the calcium phosphate may vary from 6–20

per cent., according to the type of refuse used. Several analyses give the following figures :—

Moisture..	8–14 per cent.
Organic matter	54–67 ,, ,,
Phosphoric acid	5–7·8 ,, ,,
Lime	6–10 ,, ,,
Salts, magnesia, potash ..	5–17 ,, ,,

Wet acid fish scrap.—The fish scrap after pressing is treated with sulphuric acid of 60° Bé to the amount of about 70 lb. to 1 ton of scrap. This converts some of the bone phosphate into available phosphate. Wet acid scrap usually contains 50 per cent. of water, and 6 per cent. of nitrogen in addition to the phosphate.

A British patent describes the treatment of fish or similar material with gastric or pancreatic juices, papain or other enzyme in the presence of an antiseptic. The material is then sieved and treated with carbon tetrachloride to extract oil, and the residue used as a fertiliser.

Application.—Fish guano is very variable in its composition, according to the amounts of dry matter and water present, and purchase should be guided by the amount of water present, as the drier the material the more nitrogen and calcium phosphate it will contain. The most objectionable ingredient is oil, which hinders the decay by repelling water, and the amount of oil present is an indication of its practical value.

Fish manure is useful in gardens, and has given good results with hops and mangolds. It is used directly or mixed with the soil, and is applied in autumn or spring at the rate of 1 ton per acre in the preparation of land for potatoes, turnips, and mangolds.

Bombay cotton cake.—This product is obtained from cotton seed and usually contains from 3–4·5 per cent. of nitrogen and 0·2–4 per cent. of phosphate. It is used for fertilising purposes.

Ammoniated superphosphate.—This material is a mixture of superphosphate and ammonium sulphate in fixed amounts, but sometimes part of the superphosphate is replaced by a mineral phosphate.

The mixture is made up in proportions according to requirements, and one containing 1 cwt. of ammonium sulphate and 19 cwts. of superphosphate will give a fertiliser containing about 1 per cent. of nitrogen.

The ingredients are mixed by heaping up the superphosphate, putting the sulphate on to the heap, then passing all through a sieve to mix it thoroughly. The mixture tends to cake at first, but loses this tendency after it has been mixed a little time. If the ammonium sulphate is in relatively large amounts, the tendency to set is increased, and it appears to be intimately connected with the amount of water present in the ingredients. If the mixture sets slowly, it may become lumpy and will require regrinding before use. After it is ground, the tendency to set again disappears. When the ammonium sulphate contains from 3–4 per cent. of water, the mixture sets rapidly, and can be easily reground for use, but when it sets slowly it is more difficult to grind, and often remains damp.

Ground rock phosphates make drier mixtures, and a mixture of 12 cwts. of 30 per cent. superphosphate, 5 cwts. of 58 per cent. ground rock phosphate, and 3 cwts. of ammonium sulphate is a very suitable mixture, giving about 3·1 per cent. of nitrogen, 18·0 per cent. of soluble phosphate, and 14·5 per cent. of insoluble phosphate.

Mixtures in general use contain: 9 per cent. of nitrogen

and 9 per cent. of soluble phosphate; 5 per cent. of nitrogen and 10 per cent. of soluble phosphate; and 6 per cent. of nitrogen and 12 per cent. of soluble phosphate respectively. If the mixture is required immediately the ingredients should be dry.

Bone compound fertilisers.—These materials are generally made from bone in the form of steamed bone flour, mixed with superphosphate, or with superphosphate and mineral phosphate, or with superphosphate, mineral phosphate and ammonium sulphate, to give values of nitrogen, soluble and insoluble phosphate as required.

A mixture of 9 cwts. of 30 per cent. superphosphate, 3 cwts. of 58 per cent. ground rock phosphate, 5 cwts. of steamed bone flour (containing 0·9 per cent. of nitrogen and 66 per cent. of phosphate), and 3 cwts. of ammonium sulphate gives 13·5 per cent. of soluble phosphate, 24·2 per cent. of insoluble phosphate, and 3·4 per cent. of nitrogen.

A bone manure of commerce contained 36 per cent. of soluble phosphate, 7 per cent. of insoluble phosphate, and 0·9 per cent. of nitrogen.

Rhenania nitrogen phosphate.—This fertiliser is a mixture of lime nitrogen or nitrolim, and Rhenania phosphate. It contains 9·8 per cent. of nitrogen and 7·5 per cent. of citrate soluble phosphate. It is stated to give an increased yield of sugar in sugar beet as compared with that given by ammonium phosphate.

Phosphatic peat.—A fertiliser made by absorbing phosphoric acid by means of peat.

Phosphatic nitrate.—A fertiliser produced in Sweden by acting upon mineral phosphate with a limited supply of weak nitric acid. Weak acid is used to prevent making too much nitrogen. A large amount of the phosphate remains undissolved.

Ammon-phos.—This substance is ammonium phosphate, and is made from cyanamide.

The efficiency of its nitrogen is nearly as great as that of sodium nitrate, and the material gives promise of usefulness.

Diammonphos, B.A.S.F.—A pure diammonium phosphate, $(NH_4)_2HPO_4$. It contains 19 per cent. of nitrogen and 47 per cent. of phosphoric acid. Its phosphoric acid is in a readily assimilable form, and it is stated to be a suitable fertiliser for the cultivation of cotton.

Leunaphos, B.A.S.F.—A fertiliser which is a mixture of diammonium phosphate and ammonium sulphate. It contains 20 per cent. of nitrogen and 15 per cent. of phosphoric acid.

CHAPTER VII

NITROGENOUS-POTASSIC FERTILISERS

Potassium nitrate.—The production of this substance has been an important industry in India, where it is chiefly used as a source of nitrogen and potash.

The raw material is obtained from the earth of old and more recent village sites. The huts which formed the village were made of mud, and contained floors formed from a mixture of cow-dung and mud, and these mixtures have collected over many years, and nitrification has taken place.

The earth may contain as little as 1 per cent. of nitrate or as much as 28 per cent. A good average one contains about 5 per cent. It is extracted with water after mixing with wood ashes, when the liquid drains away and is collected. It contains about 7 per cent. of potassium nitrate with large amounts of sodium chloride. It is concentrated, when sodium chloride is first deposited ; the liquid is further concentrated and potassium nitrate or saltpetre crystallises out. This crude material is used for fertilising purposes and may contain from 25–75 per cent. of potassium nitrate, the impurities being sodium chloride and sodium sulphate.

Potassium nitrate has also been made in France by mixing heaps of earth and road scrapings with decomposing organic matter, protecting from rain, and watering at intervals with liquid manure. Nitrification takes place,

the liquid draining away containing nitrates of potassium and calcium. It is mixed with wood ashes or potassium carbonate, extracted with water, and concentrated. The potassium nitrate is obtained by evaporation.

Potassium nitrate is now made in large quantities from sodium nitrate and potassium chloride by concentrating a solution of these compounds, when sodium chloride is first crystallised, and then potassium nitrate by cooling.

Although it is a valuable fertiliser it is too expensive for ordinary use, except under special circumstances.

It contains 13 per cent. of nitrogen and 45 per cent. of potash. The salt is dearer than a mixture of sodium nitrate and potassium sulphate, which mixture will supply the same ingredients.

Seaweed.—Seaweed for application as a fertilising material is largely used in localities near the sea. It is carefully collected in many parts of Jersey, Cornwall, and Devon, and the weed used either alone, or mixed with artificial fertilisers.

The best types of seaweed, that is, those which contain the highest amounts of plant food ingredients, are species of *Fucus* and *Laminaria.*

When fresh, seaweed contains about 80 per cent. of water, and it varies greatly in its composition. The amount of nitrogen is usually from 2–3 per cent. calculated on the dry material. The percentage of potash in twenty samples of *Fucus* and *Laminaria* was 3 per cent. and the phosphoric acid 0·5 per cent. *Fucus* is also known as "wrack," "black-wrack," "bladder-wrack," and "cutweed." It is easier to collect than *Laminaria,* but has a lower potash content than the latter. The dry material contains from 3–4 per cent. of potash, and the ash has a potash content on an average of 12 per cent.

Laminaria is also called "drift-weed," "may-weed," and "tangle-weed." The stems of this type contain a higher percentage of potash than the fronds, the dry stems containing from 10–12 per cent. and the fronds only 5 per cent. of potash. The ash from *Laminaria* species may contain as much as 20–30 per cent. potash. *Ulva* or "sea lettuce" is another seaweed which is particularly rich in nitrogen compounds, and is used as manure.

If grown in polluted water it gives a higher percentage of nitrogen than that grown in ordinary sea-water, and may reach as much as 4·75 per cent. of nitrogen calculated on the dry material. The water content of seaweed varies from about 68–83 per cent., the organic matter from 12–25 per cent., the nitrogen from 0·23–0·38 per cent., and the potash from 0·8–1·8 per cent.; the dried weed may contain from 64–80 per cent. of organic matter, 1·3–1·5 per cent. of nitrogen, and 2·5–10·5 per cent. of potash. The potash in the ash varied from 12·2–28·7 per cent.[1]

When collected, seaweed should not be allowed to rot in heaps as it rapidly decomposes. It should be applied at once to the land or mixed with dung. Exposure to rain very much lowers its value, as some of its fertilising constituents are washed away. The wet weed can only be used near the coast owing to the cost of carriage.

The drying or burning of good seaweed appears to be a profitable venture, and properly worked, shows promise of an excellent source of potash.

Kelp is a term usually applied to the ash of seaweed, but it is also used for the weed itself.

It is claimed that a process worked in Japan enables

[1] The use of seaweed as a fertiliser, and analyses by Hendrick are given in Sectional volume 8 of the Ministry of Agri. and Fish.

potassium chloride to be produced cheaply from seaweed, and in the same country *Ecklonia* species, *Sargassum* and *Laminaria Japonica* are burnt in carefully heated kilns for the production of iodine and potash. The kelp ash obtained by burning seaweed in Scotland contains on an average 13·5 per cent. of potash.

In America, certain varieties found on the Pacific coasts, such as *Pelagophycus pona* and *Macrosystis pyrifera*, are dried and used as fertilising material. They yield 15 per cent. of potash. Seaweed is sometimes used alone, but is also mixed with other materials for application for fertilising purposes. It is often destructively distilled to produce ammonia.

A modern process consists in fermenting the weed by means of suitable bacteria. The small amount of acid produced is neutralised with lime, and after two weeks the whole is evaporated.

Calcium acetate, valerate, propionate, the butyrate, are produced and separate out, and the esters are obtained from these salts. The next products to separate are calcium acetate and potassium chloride. Acetone and acetone oil are obtained by distillation, leaving the potassium chloride. The solution is concentrated to crystallise the potassium salt, leaving iodine in the mother liquor.

Application.—A ton of seaweed yields about 20–30 lb. of potash, which is equivalent to about 1½ cwts. of kainit, and although the amount of nitrogen is about the same as that in farmyard manure, it is not so readily available as in the latter. It, however, decays quickly in the soil, the nitrogen rapidly becoming available. It is deficient in phosphate as compared with farmyard manure, and it is often necessary to supplement it with superphosphate or other phosphatic fertiliser.

It can be applied to any crop which benefits by applications of farmyard manure, and is most valuable on land which gives good returns with green manure.

It is largely used in Scotland for potatoes, and 15–40 tons per acre are stated to give almost as good results as farmyard manure. It is useful on land liable to "finger and toe," as applications of dung often increase this disease.

Seaweed decomposes more completely than dung, and a mixture of the weed and dung is stated to give better results in improving the soil than dung alone.

Mixtures of seaweed and superphosphate give very good results with potatoes, cabbage, and mangolds. The amount used varies from 10–40 tons per acre of the weed as collected, usually supplemented with either superphosphate or basic slag, or with a complete artificial fertiliser.

The Irish Department of Agriculture have recommended 15 tons of seaweed, 1 cwt. of ammonium sulphate, and 4 cwts. of superphosphate, sometimes with 1 cwt. of potassium chloride, per acre for potatoes.

Raw wool.—This material has had a limited use as a fertiliser. It contains nitrogen and potash. In the usual way the potash is removed by the washing process to obtain this material.

Raw wool may contain from very little to 3 per cent. of potash.

Tobacco stems and dust.—These waste products contain nitrogen, potash, and small amounts of phosphoric acid. The stems are stated to contain from 1·7–2·5 per cent. of nitrogen and from 7–8 per cent. of potash, and the dust from 2·5–3·3 per cent. of nitrogen and from 2–3 per cent. of potash.

A Norwegian patent describes a process for the pro-

duction of a nitrogenous-potassic fertiliser, which consists in the treatment of a potash mineral with nitric acid to produce a mass which can be easily ground for use as a fertiliser.

Phosphatic-potassic Fertilisers

Potassic superphosphate.—This fertiliser is a mixture of potash manure salt or other potash salt with superphosphate.

The mixture can be varied according to requirements, and one containing 2 cwts. of 30 per cent. potash manure salts and 19 cwts. of superphosphate gives a fertiliser containing 3 per cent. potash and 28·5 per cent. soluble phosphate.

A mixture containing 5 cwts. of 20 per cent. potash manure salts and 15 cwts. of 35 per cent. superphosphate will give a material containing 5 per cent. of potash and 26 per cent. of soluble phosphate.

Unless chloride is present in considerable quantities, the mixture tends to become drier than superphosphate alone, but if chloride is there in large amounts the fertiliser will become damp after keeping.

Application.—These mixed fertilisers are stated to be very suitable for grass land.

Mangolds, with dung and 5 cwts. of potassic superphosphate containing from 29–39 per cent. of soluble phosphate and 7 per cent. of potash, with 5 cwts. of common salt and 2 cwts. of sodium nitrate as top dressing, are stated to do well.

Cotton-seed meal ashes.—This product, containing about 10 per cent. of phosphoric acid, 8 per cent. of which is available, and from 17–18 per cent. of potash, has been used as a fertiliser.

CHAPTER VIII

NITROGENOUS-PHOSPHATIC-POTASSIC FERTILISERS

Farmyard manure.—It is estimated that about forty million tons of the material known as farmyard manure, fold manure, dung, or muck, are made annually in the United Kingdom.

It consists of the litter, usually straw, but sometimes peat moss, bracken, or other material, mixed with the excreta and the urine of the animals upon it. The solid part voided by the animals consists of the undigested portion of the food which has been supplied to them, and the liquid part, that which has been digested but has not been retained in the system.

The manure will vary considerably in its composition according to the character of the material used as the litter. The common litters are straw, peat moss, bracken, hop-bine, leaves, spent tan, and sawdust, the most used being straw.

These substances not only differ in themselves, but also in their power of absorbing the liquid portion of the manure. Since most of the nitrogen and potash is found in the urine, it is obvious that sufficient should be used to absorb all this commodity. Straw and bracken used as litter give a manure very suitable for heavy soils, and although farmyard manure should not contain too much straw litter, heavy land is considerably improved by dressings of strawy manure.

The litter used will depend upon the material available, but it should be remembered that they also enrich to some extent, in that they have certain fertilising value in themselves. Dried and shredded peat moss is often used in city stables because of its high absorbing power, but it is lower in its potash content than straw.

Straw contains about 0·45 per cent. of nitrogen, 0·2 per cent. of phosphoric acid, and 0·9 per cent. of potash. Peat moss and bracken contain more nitrogen than straw, but have a lower potash value. Sometimes it is an advantage to mix peat moss with the straw for use as litter. Peat moss has one drawback, in that it undergoes decay with difficulty.

Tanners' refuse is poor in fertilising value.

In regard to the manure, the three most important substances in animal food from the point of view of manuring, are nitrogen, phosphorus, and potassium.

About one-half of the solid matter in the food reappears in the manure, but it contains most of the nitrogen, phosphorus, and potash. The proportions of these ingredients are increased in the case of fully-grown fattening cattle, and reduced in the case of young animals.

The larger amount of the nitrogen and potash finds its way into the urine, but the phosphate is chiefly found in the dung. It is therefore obvious that the liquid part is more valuable than the solid, in that it contains two of the most important constituents. These two substances are also in a more available form as suitable food for the plant. Especially is this the case with the nitrogen compounds which rapidly change into ammonia, and other useful substances. The solid excreta is, however, more resistant, and not so readily available as plant food.

The liquid portion is rich in potash, and it is stated that

1,000 gallons contain on an average 20 lb. of nitrogen, 3 lb. of phosphoric acid, and 46 lb. of potash.[1]

The variation in composition and quality of manure depends upon the nature of the litter, but more particularly upon the number and kind of animals littered upon it, and the quantity and quality of the food consumed by them. The composition of the food is not the only factor, for its digestibility is also important, as a food which is hard to digest by the animal is equally hard for soil bacteria to split up and convert into suitable plant food. On the other hand, the digestible portion is easily converted into available plant nourishment.

Finally, and this is very important, the value of the manure will depend upon the mode and duration of storage.

The composition of farmyard manure is, of course, very variable, but the following figures give some idea of the approximate value.

Water	75 per cent.
Organic matter	22 ,,
Nitrogen	0·45–0·65 per cent.
Potash	0·4–0·8 ,,
Phosphoric acid	0·2–0·4 ,,

Generally, it may be stated that the richer the food in fertilising materials, especially nitrogen, the more valuable is the manure produced, more particularly in the liquid portion.

Concentrated foods, such as cake, improve the manure, and the richness of the cakes, in terms of manure, is represented by the nitrogen content, not by the oil, although from a food point of view, the one with the more oil is the richer. The oil and the carbohydrates in the food are used by the animal, but the fertilising materials,

[1] Hendrick, *Aberdeen Bull.* No. 19, 1915.

nitrogen and potash, pass mainly into the urine. Some idea of the value of cattle foods may be gathered from the following table.[1]

Food.	Nitrogen (per cent.)	Potash (per cent.).
Decorticated cotton cake ..	6·9	2·0
Linseed cake	4·7	1·4
Coconut cake	3·4	2·0
Oats	2·0	0·5
Oat straw	0·5	1·0
Swedes	0·25	0·22

Horse manure is poorer in nitrogen than farmyard manure, and it ferments more rapidly, and therefore acts more quickly, whereas that from cattle and pigs is slow acting, and consequently more durable. Young animals and dairy cows give poorer manure, for the reason that in the first case the elements of plant food have been used to form bone and muscle, and in the latter have found their way into the milk. Fatting animals retain least of the important constituents, growing stock more, and milch cows most. The variation in the type of manure, including litter, from different animals is shown in the following table.[1]

	Per cent. Total nitrogen.	Per cent. Phosphoric acid. P_2O_5	Per cent. Potash. K_2O
Bullock	0·62	0·26	0·72
Cow	0·43	0·19	0·44
Horse	0·54	0·23	0·54

The storage of farmyard manure presents considerable difficulties, for when it is kept under the best conditions there will often be a loss of 15 per cent. of its nitrogen, and can be as much as 40 per cent. under ordinary methods of storage, and under bad conditions it may lose 75 per cent.

The storage is simplified if the cattle are kept in covered sheds, with sufficient litter to absorb the urine, and there

[1] Russell, *Manuring for Higher Crop Production.*

is little or no drainage. The dung is well pressed together, and this means that fermentation is reduced to a minimum.

Out in the open the case is entirely different, and wet weather will account for very heavy losses, in that it will wash out much of its most valuable constituents. A system of drainage is sometimes practised, and in the case of dairy cows kept in stalls, the liquid manure is highly valuable. It is applied during showery weather, or diluted, for the strong liquid tends to burn foliage. It is stated that ammonium bisulphate added to liquid manure will prevent to a large extent losses of nitrogen.

Farmyard manure thrown out into the open involves heavy losses, and if it is impossible to keep it in dung-sheds, or other covered places, it should be drawn out and made into heaps. The heap should be made by building it up, pressing it down tightly, and covering it with a foot of earth. It is an advantage to form a sloped heap, so that the rain may run down instead of into the mass. This will preserve to some extent its manurial constituents. Exposure to weather under any condition means considerable loss, even greater than an analysis will show.

Even when stored under the best conditions farmyard manure loses a good deal of its most valuable plant food, and under bad conditions the loss may be very great. It must be remembered that the loss first affects the most available material, and is proportionally greater in the case of cake-fed manure than in material of a lower quality. It therefore follows, that if animals are well fed to produce good manure, extra precautions must be taken to insure against loss in its storage.

It is wasteful to turn heaps of manure to get at the well-rotted material for top dressings. Directly the heap is broken it should be used.

The chief causes of loss are the escape of the liquid portion of the manure, and the loss of ammonia as a result of fermentation. In the first case, it is important to recognise that most of the manurial value is associated with the urine. The escape of the ammonia occurs more when the material gets dry, and is exposed to air, and every time the manure is disturbed, air is introduced, and fermentation encouraged.

It is advisable to get the dung into the soil as soon as possible, as the losses in the soil are less than under any system of storage.

Well-rotted dung is richer and more active than comparatively fresh, undecomposed material. It is, however, necessary to remember that manure cannot be rotted or stored without serious loss, and while the rotted material may contain more plant food than an equal weight of fresh manure, it contains actually less than the fresh manure from which it is made.

Gypsum, superphosphate, and kainit, as well as other materials, have at times been recommended as agents suitable to conserve or prevent loss of the constituents of the manure. These substances have sometimes been applied with success, but it is generally recognised that under most conditions, they are open to objection.

As farmyard manure must first decompose in the soil, its full benefit may only be felt after some time if the land has been well cultivated, drained, and limed. The duration of its action depends upon the nature of the soil. In open soils it is used more rapidly, but on the heavier types, it may take years to obtain the full value.

Farmyard manure supplies plant food, and one of its chief properties is to restore much of the nitrogen previously taken from it in the form of straw, as well as some

phosphoric acid and potash, but to obtain the best results artificial fertilisers must be used in conjunction with it. It has, however, a marked effect upon the mechanical condition of the soil. Heavy soils are as a rule poor in lime and phosphoric acid, although they are relatively rich in potash and nitrogen.

When used for arable purposes, farmyard manure is necessary to break up the soil into a more open condition.

A valuable property of the manure is its power to hold water, artificial fertilisers having very small effects compared with it. A ton of farmyard manure is of course more difficult and expensive to handle than from 2–3 cwts. of an artificial fertiliser, and this reduces its relative value. It must be remembered, however, that the manure has a beneficial although indirect influence upon crops for the very reason that it is bulky.

No fertiliser exactly suits every crop, and farmyard manure alone will often lack enough of a particular plant food, even though it contains three of the most important constituents. Certain crops require more phosphoric acid than it contains, whilst others need more nitrogen.

Mangolds require more nitrogen than the manure is able to supply, and considerable increases in this crop have been obtained by the addition of sodium nitrate; turnips need more phosphate than the manure carries.

If used for rotation crops, farmyard manure will not always last in regard to its plant food, although its physical effect upon the soil is felt for some years. The loss in plant nutrient is considerable with a first crop of potatoes, and it must be supplemented in the spring by a dressing of artificial fertiliser. An economical method for preventing the loss of manurial value is to feed sheep on a root crop on the field where the soil is not too wet. This reduces

the loss of manure to a minimum and fertilises the soil for the next crop.

In many cases the application of artificial fertilisers in addition to dung increases the yield to even a higher value than by adding more dung, and beyond certain limits the addition of dung gives very small increases in yield and improvement of the crop.

It has been found that the yield from some lands manured with 20 tons per acre of farmyard manure was only slightly better than that from 15 tons, whereas 15 tons supplemented with ammonium sulphate, superphosphate, and kainit gave the highest yields.

Application.—Much depends upon the circumstances in each case, but on farms under grass it is usual to cart it out as opportunity occurs in autumn, winter, and early spring. It is most economical to apply it to the land as soon as it is taken out of the yards, but this will depend upon the climate and the crop.

The application of fresh manure to the soil conserves its nitrogen, but there is a risk of excessive denitrification being set up in the soil both by the large amounts of organic matter present, and the denitrifying organisms in the straw. The addition of kainit or superphosphate has been recommended as a means of preserving the nitrogen.

It should also be remembered that excessive amounts of fresh manure often diminish the effect of rapidly acting fertilisers such as sodium nitrate and ammonium sulphate.

The needs of the particular crop must be studied, as some plants do well with large amounts of fresh manure, but others do not benefit at all with the fresh material.

It is stated that potatoes do better with a spring dressing and mangolds with a winter one. On heavy soils it should be dug in during autumn and winter, but

in the case of lighter ones this should be done in the spring.

Undecomposed manure should preferably be used for green crops, and the more decayed portion for root and fruit crops.

The nitrogen in the manure from cake-fed animals is readily available, and in consequence its essential constituent will be partially lost, especially if the soil is left without crop during a wet winter. It is wise to put the best manure on the crop expected to give high yields, and then follow with another crop as rapidly as possible.

Most farmers use the manure made on the farm on their root crops, and in some cases on the heavy crop.

It is important that farmyard manure be distributed as evenly as possible. If left in small heaps, the ground where the heaps lie are likely to be over-manured, or the land manured in patches. Potatoes are often manured with 20 tons of manure per acre, but from 10–15 tons of dung with the addition of a complete artificial fertiliser give better results.

Mangolds do well with 20 tons per acre, but as they require more nitrogen, an artificial nitrogenous fertiliser is added.

Beans are stated to give good results with farmyard manure.

Swedes and turnips are usually manured with from 10–15 tons per acre, with the addition of a fertiliser rich in phosphate.

Green crops such as cabbages and sprouts require more dung than any other crop, and sodium nitrate as a top dressing is valuable. Some farmers use 10 tons per acre of half-rotted manure for onions. Fresh manure should not be used for this crop.

Wheat generally requires dung, but it is usually applied to the crop preceding it, often potatoes. Potash and nitrogen are often needed in addition.

Barley is stated to give good results with farmyard manure.

For hay land from 10–12 tons per acre is a suitable amount.

Mention must be made of the "finger and toe" disease of turnips, which is often spread by the use of farmyard manure, if the diseased vegetables have been thrown on the manure heap or the animals have been fed on them. Lime appears to be the best preventative.

Synthetic farmyard manure.—The shortage of farmyard manure led Richards and Hutchinson to experiment at Rothamsted with the preparation of a synthetic product, and it was found that by treating wet straw with a certain amount of combined nitrogen and maintaining the reaction of the mixture faintly alkaline, it was possible to convert the straw into a product similar in composition to farmyard manure. The process proceeds much better when the material is freely supplied with air.

Field trials have given promising results and the process has been patented.

Many other waste products have been treated and successfully converted into synthetic farmyard manure.

Wheat, oat, and barley straw are suitable materials for the manufacture of this product, and 70 tons of straw yield about 180 tons of the manure.

The fermentation of a compost containing paddy straw and calcium cyanamide is practically complete after 69 days.

The addition of certain substances such as urine, urea, ammonium carbonate or peptone to damp straw produces

a product similar to well-rotted stable manure. In a series of experiments in which urea was added in sufficient amount to make the total nitrogen range from 71–1044 milligrams, the total nitrogen varied between 176 and 337 milligrams after rotting three months. When the added nitrogen exceeded 0·75 part per 100 parts of damp straw, ammonia was lost by volatilisation.[1]

Green manure.—When farmyard manure or stable manure is scarce, green manure is a suitable form in which to supply organic matter to the soil, to keep up the supply of the valuable humus.

The method consists in sowing some rapidly growing crop and digging it in before the ripening stage, which can be done on land which has become vacant. Rye sown in September can be dug in in March, and mustard sown in July and August can be dug in in October or November.

Suitable crops for the purpose are mustard, rye, vetches, rape, clover, tares, barley, and peas. In Germany, lupins have been successfully used.

Vetches, peas, and clover have some advantage over other crops in that they have nitrifying bacteria on their root hairs, and nitrogen from the air can be absorbed by them.

Tares give a large amount of nitrogen to the soil.

If these green crops are heavily fertilised during growth, and then dug in, the succeeding main crop will greatly benefit, and it is the custom on lands poor in organic matter to enrich the soil in this manner.

The ploughing in of green crops brings about considerable improvement in the soil, especially on light land, and

[1] H. B. Hutchinson and E. H. Richards *Trop. Agri.* (*Ceylon*), 64, 24–30 (1925).

it has greater effects upon sandy soils than stiff ones. The effect upon the soil will depend on the nature of the crop and its bulk.

The growing of these crops for green manuring also has the effect of using up the nitrates in the soil which would otherwise be washed out at this season of the year. When the crop is dug in it provides nitrogen for the next crop, and also brings about nitrification.

It does not add any mineral constituents, and phosphoric acid, potash, and lime are unaltered in their amounts, although they may become more available. Sometimes these crops are eaten by stock before ploughing the land.

Sugar beet waste is also used as a form of green manure. In addition to the bone black which has been used to decolorise the sugar juice, the pulp and beet tops, if unsuitable for use as feeding stuffs, are applied directly as fertilising materials.

Poultry manure.—This material, the annual amount of which is estimated at 1,000,000 tons in England and Wales, has considerable value as a fertiliser. The quantities produced by 100 fowls of different kinds has been ascertained very completely, as the following figures show.

Breeding birds give 80 cwts. of fresh manure in one year. Chickens, from the hatching stage until 13 weeks old, give 9 cwts. in this time, and fattening fowls in three weeks yield 5 cwts. of fresh manure.[1]

The composition of the manure depends upon the type of bird, fattening birds giving a richer dung than laying ones.

It is a richer fertiliser than farmyard manure, and as its nitrogen is readily available, it is a quick acting one.

The average nitrogen content of fresh fowl dung is

[1] *Journ. of Board of Agri.*, vol. 13, p. 719, March 1907.

1·9 per cent., the phosphoric acid 1·0 per cent., and the potash 0·55 per cent.

The dried material contains 5·2 per cent. of nitrogen, 2·5 per cent. phosphoric acid, and 1·4 per cent. potash.

Peat moss, sawdust, or gypsum are sometimes added to the material to dry it, but fine soil is quite as effective.

It should be kept in a similar way to farmyard manure, by covering it with earth.

Application.—A good poultry manure is as effective as a quarter of its weight of sodium nitrate or its equivalent. It has given good results when compared with other nitrogenous manures, especially with the addition of superphosphate. The amount used is usually from 8–10 cwts. per acre.

It is valuable as a forcing manure for green crops as a top dressing, and is also useful for strawberries, fruit trees, and tomatoes. For turnips, grass, and on heavy land, it should be used with superphosphate, and for potatoes, mangolds, and on light soils, potash should be added as well as phosphate.

Pigeon dung.—This material contains from 1·2–2·4 per cent. of nitrogen, 1·7–4·0 per cent. of phosphoric acid, and 1·1–2·0 per cent. of potash, and is a valuable fertilising material.

Ducks' dung.—This substance has a nitrogen content of 0·8–1·0 per cent. of nitrogen, 1·4–3·5 per cent. of phosphoric acid, and 0·6–0·8 per cent. potash.

Geese dung.—This has a lower value than the preceding, and contains from 0·6 per cent. of nitrogen, 0·5–0·9 per cent. of phosphoric acid, and 1·0–1·2 per cent. potash.

Sea birds' dung.—This material occurs on the cliffs and shores, and is rich in nitrogen and phosphoric acid, with smaller amounts of potash.

Bats' guano.—Deposits of this commodity are found in caves in tropical countries, sometimes in sufficient amount for use as a fertiliser. It is usually applied in the localities where it is found, and is not regarded as being of great value as a fertiliser.

Its composition varies considerably, and depends upon the amount of water present. One sample gave 8·2 per cent. of nitrogen, 3·8 per cent. of phosphoric acid, and 1·3 per cent. of potash. Deposits in Africa, consisting of silt, bats' dung, and bones, have a very variable composition.

Peruvian guano.—The original Peruvian guano, first sent to England in 1839, and consisting of deposits of the dried dung of birds, together with portions of feathers, bones, and refuse of food, was a very valuable and concentrated fertiliser, with its ingredients readily available for plant life. It contained nearly half its weight of ammonium salts in the forms of urate, oxalate, and phosphate, together with calcium phosphate and potash compounds. It contained from 12–16 per cent. of nitrogen, and from 13–14 per cent. of phosphoric acid. Its high nitrogen content was due to the fact that in Peru the climate is hot and dry, and the excrement of the birds quickly dried and the nitrogen was held.

In a moist climate, the nitrogen is rapidly converted into ammonia, which is lost by volatilisation. These deposits have now become exhausted.

The term guano is frequently applied to fish, meat, and blood preparations, but these products have little in common with the original guano.

Considerable importations of Peruvian guano are still made, from more recent deposits. The fresh excrements are very nitrogenous, and consist chiefly of uric acid and

phosphate, and if the climate is hot the deposits are dry and the nitrogen remains in the material as in the case of the original substance. Phosphatic guanos are found in the wet districts, and owing to the loss of nitrogen as ammonia, they are valuable only as phosphatic fertilisers.

The more recent supplies of guano now come from new deposits on certain islands of Peru.

The nitrogen in the guano is partly in the form of ammonium salts and partly in organic combination; the phosphoric acid is in the form of finely divided calcium phosphate, usually soluble in water, and the rest soluble in dilute citric acid. An appreciable amount of potash is also present.

Modern guanos are very variable in composition, and usually contain from 2–11 per cent. of nitrogen, 15–40 per cent. of calcium phosphate, and 1–4 per cent. of potash.

A bird guano obtained from Ichaboe, off the coast of Africa, contains from 7–12 per cent. of nitrogen, and 5 per cent. of phosphoric acid. It is similar to Peruvian guano in its composition, and some of its nitrogen is in the form of feathers.

Damaraland guano contains about 34 per cent. of organic matter, with a nitrogen content of 7·7 per cent. The ash amounts to 47 per cent., and it contains 11 per cent. of phosphoric acid, and 2·5 per cent. of potash. Other types of guano contain from 0·5–2·0 per cent. of nitrogen, and from 23–34 per cent. of phosphoric acid.

Deposits of a similar material are found on the Caribbean coast. They are low in nitrogen, but are higher in phosphorus than the Peruvian variety.

Nitrogenous guanos are very valuable fertilisers, because the nitrogen is in an available form, and the phosphate is mainly soluble. Owing to the variability of its com-

position, importers frequently prepare a mixed or equalised guano containing a fixed amount of nitrogen. It is also sold unmixed.

Dissolved guano, manufactured by treatment with sulphuric acid to fix the ammonia and render the phosphate more soluble, is another product of considerable value. It contains a definite amount of nitrogen and soluble phosphate.

Oil-cakes.—Cheap or damaged cakes or cakes unfit for food, such as castor cake, are employed as fertilisers, but more particularly the residual meals obtained as by-products in the extraction of the oil by solvents from rape, castor, and other oil-seeds are used. They have been applied considerably in hop manuring, and for general use on light soils, when a slower-acting fertiliser is preferred. They usually contain from 4–7 per cent. of nitrogen, 1–3 per cent. of phosphoric acid, and 1–2 per cent. of potash.

Castor cake—Castor meal.—Castor seeds are pressed largely in India for obtaining burning oil. The oil is also used for lubricating, and is produced by several methods, one of which consists in soaking the seed in water, grinding up, and allowing the oil to escape through a hole in the mortar mill. Castor cake is frequently milled and sold as meal. It contains on an average from 4–7 per cent. of nitrogen, 1·5–3·5 per cent. of phosphoric acid, and 1·9–2·5 per cent. of potash. When finely divided it is suitable for application to the land.

Cotton-seed meal.—A product obtained by grinding the cake which is left when the oil is pressed out. It is mainly used for its nitrogen content, and contains from 7–10 per cent. of nitrogen, 1–3 per cent. of phosphoric acid, and 1·5–3·0 per cent. of potash.

Several Bombay cotton cakes yield from 3–4·5 per cent. of nitrogen, 0·2–4·0 per cent. of phosphoric acid, and only small amounts of potash.

Linseed meal.—This material contains from 3·5–5·5 per cent. of nitrogen, 1·2 per cent. of phosphoric acid, and 1–2 per cent. of potash, and is sometimes used as a fertiliser.

Tung oil cake.—This cake often contains from 3·5–4·5 per cent. of oil. The contents of its fertilising ingredients are about 3 per cent. nitrogen, 1 per cent. of phosphoric acid, and 1 per cent. of potash.

Town refuse.—The refuse of towns, consisting of the contents of refuse bins, dry ashpits, that from ash closets, and street sweepings, as well as night soil, which consists of excreta, and is the product of towns where the pail system is in use, are all used as manuring materials.

They are mixed or used alone, and vary tremendously in their amounts of available plant food. In some towns the products are sieved or mixed with material such as night soil, to give more valuable products.

Night soil, when dried and granulated, contains about 5 per cent. of nitrogen, 5 per cent. of phosphoric acid, and 2·5 per cent. of potash, and a mixture of this material with the contents of refuse bins and ashpits gave a material containing 3 per cent. of nitrogen, 3·6 per cent. phosphoric acid (half of which is soluble), and 1·2 per cent. of potash.

Street sweepings and night soil are well known, and a mixture of night soil and ashes is also sold.

In some towns the refuse is sorted, and cans, bottles, metal, and cinders are removed. It is then often improved by the addition of street sweepings, slaughter-house refuse, or stable manure, and then contains from 25–40 per cent. of organic matter, 0·4–0·6 per cent. of nitrogen, 0·3–0·5

per cent. of phosphoric acid (equal to 0·7–1·1 per cent. of calcium phosphate), and 0·3–0·5 per cent. of potash.

It is not comparable with farmyard manure, as its constituents are so variable, and some may have no manurial value.

Ashpit refuse has good physical effect upon the soil, but its fertilising properties may be very small.

In Northern towns, night soil, street sweepings, market manure, and stable manure are added, and a richer material results. It is ground and sieved, and contains a considerable amount of human excretions.

A Gateshead product of this type gave good, but not quite so good results as farmyard manure.

The following table showing the composition of ashpit refuse as prepared by certain towns, as well as most of the information on these products, has been taken from the Ministry of Agriculture and Fisheries Sectional Volume 8.

	Gosforth. Pulverised refuse, "mixed."	Bury. Pulverised refuse, "mixed."	Sheffield. Separated dust.	Falkirk. Separated dust.	Southwark. Dry refuse.	Hove. Dry refuse.	Halifax. Night soil and separated dust.
Organic matter	23·1	3·6	28·6–37·5	20·51	26·96–32·04	—	21·7
Nitrogen	0·5	0·55	0·57–0·7	0·39–0·56	0·7–1·21	0·56–0·84	2·13
Phosphoric acid, P_2O_5	0·19	0·33	0·45–0·77	0·33–0·81	1·09–1·15	0·56–0·82	0·56
Potash, K_2O	0·39	—	0·33–0·64	0·42–0·54	0·60–0·64	0·43–0·60	—

Application.—Town refuse, which is of a very varied character, has given good results on heavy land allotments where it is used for root crops and cabbages, and for

raising the level of low-lying wet land, forming new land for allotments. It is used on land near towns, and 10 tons per acre is the usual dressing. It lightens heavy soil.

Beet sugar waste.—In addition to the use of beet tops and pulp as green manure, and of the spent char as a source of phosphate, several attempts have been made to utilise the waste vegetable refuse and concentrated sugar residues for fertilising purposes.

One method consists in treating the waste vegetable refuse and other waste material with ammonia and sulphur dioxide to form a composite fertiliser, and a United States patent describes a method of treating concentrated sugar residues with sulphuric acid, and heating, then adding lime, mixing with acid phosphate and drying, or heating with sulphuric acid until a dry product is obtained.

Cane sugar refuse.—A fertiliser is made from the ashes of the begasse furnace, defecation scum, and distillery slop, by putting the ash into a brick reservoir, adding the scum, and heating. When dry, the slop is run in and the mass dried. It is stated to contain 1 per cent. of nitrogen, 4·2 per cent. of phosphoric acid, and 3·3 per cent. of potash.

Brewers' grains.—The residue left after barley or other grain has been extracted with hot water, if unsuitable for feeding, has direct fertilising value, and if cheap can be used with advantage. It also has a good physical effect on the soil.

The wet material contains 76 per cent. of water, 0·62 per cent. of nitrogen, 0·42 per cent. of phosphoric acid, and 0·05 per cent. of potash, and the dry substance has 9 per cent. of water, 2·51 per cent. of nitrogen, 1·61 per cent. of phosphoric acid, and 0·2 per cent. of potash.

Spent hops.—These have a similar composition to the brewers' grains, and can be used as a fertilising material.

Distillers' wash.—A British patent describes a method of producing a fertiliser from this material, by treatment with sulphuric acid to neutralise alkali, and decompose the organic matter. A small quantity of peat, straw, rice, or sawdust is added and the mixture dried.

Dairy waste.—A suggested method for the production of a fertilising material from dairy waste consists in treating the material with ferrous sulphate and lime and using the precipitate produced as a fertiliser.

Fermented wheat dust.[1]—A sample of wheat dust containing 1·33 per cent. of organic nitrogen, 0·73 per cent. of phosphoric acid, and 0·53 per cent. of potash, was inoculated with farmyard manure and with soil, and allowed to ferment. The protein content dropped from 1·6 to 1·03 per cent. in seven weeks, remaining constant after this, and the ammonia content increased correspondingly.

In pot experiments the fermented dust gave comparable results with farmyard manure.

Tapioca refuse.—This material contains 11·6 per cent. of moisture, 59·7 per cent. of organic and volatile matter, and gives an ash of 28·7 per cent. It contains 0·61 per cent. of nitrogen, 0·56 per cent. of phosphoric acid, and 0·58 per cent. of potash, and is suitable for use on the spot as a fertilising material.

Cocoa shells.—These are often ground and sold for fertilising purposes, and contain on an average 2·5 per cent. of nitrogen, 0·75 per cent. of phosphoric acid, and 2·5 per cent. of potash.

Cocoa cake.—Formerly only the shells and waste substances such as the dust and sweepings were used as

[1] *Report Dept. Agri. Punjab*, 1922–3, Part 2, 72–123 (1924).

fertilising materials, but owing to the heavy demand for cocoa butter, both solvent extracted cocoa and cocoa press cake are available for this purpose.

Ground cocoa cake is used in America as a rough fertiliser, and as an ingredient in mixed fertilisers.

The production of a nitrogenous-phosphatic-potassic fertiliser from sewage has been described by a British patent, and consists in filtering the sewage through peat, peat-litter, charcoal, peat-coke, street sweepings, or house refuse, and the product mixed with ground limestone or phosphate rock. Sulphuric acid may be used to treat the filtered material to fix the ammonia.

A United States patent gives a method of obtaining a fertiliser by treating phosphate rock with nitric acid.

Leunaphoska, B.A.S.F.—This is a concentrated fertiliser specially prepared for Eastern markets. It contains 13 per cent. of nitrogen, 10 per cent. of phosphoric acid, and 13 per cent. of potash.

Nitrophoska.—A concentrated nitrogenous-phosphatic-potassic fertiliser of German origin. It is made by the conversion of potassium chloride into the nitrate and then combining this potassium salt with phosphoric acid. It is a recent product, and is being produced at the rate of 10,000 tons per month at present, but it is expected that this amount will be increased.

It is made in two grades: (1) for heavy soils and containing 17 per cent. of nitrogen, 11·7 per cent. of soluble phosphoric acid, and 21 per cent. of potash; and (2) for light soils, with 14·7 per cent. of nitrogen, 10·2 per cent. of phosphoric acid, and 26·6 per cent. of potash.

Nitrophoska is stated to have one-third of its nitrogen in the form of nitrate-nitrogen combined with potash, and

two-thirds as ammonia-nitrogen combined with phosphoric acid. It is stated to be quite neutral and free from toxic materials.

As a result of the production of Nitrophoska, the manufacture of Leunaphos and Leunaphoska has been discontinued.

CHAPTER IX

COMPOUND OR MIXED FERTILISERS

THE corn, grass, and potato fertilisers of commerce are often made by mixing ammonium sulphate or other nitrogenous material with superphosphate, with or without the addition of potash.

Turnip manures and similar products are sometimes made by the addition of a nitrogenous fertiliser such as ammonium sulphate to crushed bones, powdered hoofs and horns, or shoddy, and mixed with sulphuric acid as in the superphosphate process.

A commercial turnip manure contained 1·5 per cent. of nitrogen, 16 per cent. of soluble phosphate, and 9 per cent. insoluble phosphate, and a sample of an ordinary corn manure contained 3·17 per cent. of nitrogen, 19 per cent. of soluble phosphate, 5 per cent. of insoluble phosphate, 0·21 per cent. of potash, and 32 per cent. of gypsum.

Complete compound fertilisers can be obtained by mixing on the farm the necessary ingredients, or by having them made up by a merchant according to a specification.

In making these fertilisers the ingredients should be thoroughly mixed in small quantities at a time, either in a mixing machine, or by building up into heaps and passing through screens.

The usual procedure is to mix by spreading one material, usually superphosphate, levelling, adding the next

ingredient, again levelling, and adding another if required. This mixture is turned well and made into a conical heap, when it is then put through the screen.

If the mixture is not to be used directly, it should be allowed to lie in heaps, and if any setting takes place, broken up and bagged after that event. It may then be kept for some time.

The most usual materials used are superphosphate or ground rock phosphate, or a mixture of both, bone flour, ammonium sulphate, or rape dust, and potash salts, which can all be mixed or blended. Salt and gypsum may be added if needed. Rape dust checks the setting properties.

It is advisable not to use too much rock phosphate or other material containing calcium carbonate or reversion of the superphosphate takes place. Basic slag, basic calcium nitrate, or wood ashes, when added to superphosphate or dissolved bones, leads to the conversion of soluble into insoluble phosphate. Bone manure and superphosphate, if mixed and left, causes a reversion to the less valuable reverted phosphate.

In making these mixtures it should be remembered that ammonium sulphate or other ammoniacal fertiliser, must not be mixed with any material containing free lime, such as basic slag or basic superphosphate, or with mineral phosphate containing much chalk, as ammonia will be liberated with considerable loss.

Ammonium sulphate can be mixed with bone fertilisers, fish meal, superphosphate, salt, and potash salts.

Dissolved bones can be mixed with potash fertilisers, and basic slag with kainit.

If sodium nitrate be mixed with ammonium sulphate, ammonium nitrate and sodium sulphate are formed, becoming deliquescent.

Mixtures of ammonium sulphate with superphosphate, or both of them with salt and kainit, if not used immediately after mixing become damp or set hard according to their condition. This can be obviated by including in the mixture bone flour or castor meal. Nitrate of soda should not be mixed with superphosphate or dissolved bones, as the mass becomes sticky, and there is some loss of nitrogen as ammonia. A proportion of bone meal will remedy this.

Sodium nitrate can be mixed with potash salts.

Calcium cyanamide can be mixed with basic slag, bones, or potash fertilisers, and with dry superphosphate.

Calcium nitrate does not mix well.

A mixture of superphosphate and basic slag is sometimes made as it is easily distributed, although the phosphate becomes less soluble in water. It is, however, soluble in the soil water.

Superphosphate and bone meal form a good mixture.

General mixtures.—The type of mixture depends upon the price and availability of the materials. The following are general mixtures suitable for average conditions, and are the amounts per acre.

$\frac{1}{2}$–$1\frac{1}{2}$ cwts. ammonium sulphate.
$1\frac{1}{2}$–$3\frac{1}{2}$ cwts. superphosphate.
$\frac{1}{2}$–1 cwt. steamed bone flour.
$\frac{1}{2}$–$\frac{3}{4}$ cwt. potassium sulphate.

Other ingredients in equivalent amount may be used instead. The larger amounts of superphosphate are for swedes, turnips, potatoes, carrots, and leguminous crops, and the higher proportions of ammonium sulphate for cereals, mangolds, and hay. The steamed bone flour acts as a drier and aids distribution.

The percentage composition of a mixture may be ascertained by multiplying the weight in cwts. of each fertiliser by its content of plant food, nitrogen, phosphate, or potash, and dividing by the total weight of the mixture.

1 cwt. ammonium sulphate containing 20 per cent. of nitrogen.
3 cwts. superphosphate containing 30 per cent. soluble phosphate.
$\frac{1}{2}$ cwt. steamed bone flour containing 1 per cent. nitrogen and 60 per cent. insoluble phosphate.
$\frac{1}{2}$ cwt. potassium sulphate containing 49 per cent. potash.

Ammonium sulphate $=\frac{1\times 20}{5}=4$ per cent. of nitrogen.

Superphosphate $=\frac{3\times 30}{5}=18\cdot 0$ per cent. sol. phosph.

Steamed bone flour $=\frac{0\cdot 5\times 1}{5}=0\cdot 1$ per cent. nitrogen.

" " $=\frac{0\cdot 5\times 60}{5}=6\cdot 0$ per cent. insol. phosph.

Potassium sulphate $=\frac{0\cdot 5\times 49}{5}=4\cdot 9$ per cent. potash.

The mixture therefore contains 4·1 per cent. of nitrogen. 18·0 per cent. of soluble phosphate, 6·0 per cent. of insoluble phosphate, and 4·9 per cent. of potash.

Special Fertilisers

Many materials, some of which do not contain the substances considered necessary for plant life, have been recommended from time to time for use as fertilisers, and

the following are among those which have been mentioned in the literature of recent years. Some of them are proprietary preparations.

Their value as fertilising materials varies considerably, and some of them are applied for particular purposes, others have an effect upon the soil and improve it, whilst several contain the necessary food material for the plant.

Asahi Promoloid.—A by-product obtained by the Ashi Glass Co. of Japan. It contains a colloidal silicate of magnesium, and is stated to accelerate the growth of plants. Its moisture content is 88 per cent. and the dry material contains 17·68 per cent. of magnesia, 0·384 per cent. phosphoric acid, and 0·85 per cent. of potash.

Pot experiments showed some increase in the seed of the soy bean.

Clumina.—A fertilising material obtained by treating humus with chlorine. Horse manure, guano, peat and other substances may be treated in the same way.

Fosfaragonite.—A calcareous fertiliser which is stated to give on analysis the following figures :—

39 per cent. of carbon dioxide.
1 per cent. of phosphoric acid.
4·5 per cent. of silica.

Kalikalk.—A product prepared from potash, felspar, limestone, and gypsum. On analysis it gives approximately 37 per cent. of silica, 9 per cent. of sulphuric acid, 5 per cent. of potassium, and 32 per cent. of calcium.

It is stated on trial to give somewhat better results than potassium sulphate.

Kaliuzoto.—A new Italian fertiliser containing nitrogen,

potash, and organic matter. It is obtained by absorbing the residual molasses by means of kieselguhr until the mass becomes solid. It is stated that the porous silica which is obtained as a residue when leucite is decomposed by hydrochloric acid in the Blanc process, also readily absorbs the molasses, and offers opportunity of utilising the by-product of this industry.

If this silica is used the fertiliser is stated to contain 1·1 per cent. of nitrogen, 0·35 per cent. of phosphoric acid, 4·42 per cent. of potash, and 20 per cent. of organic matter. Some sugar refineries use the material on their own beet fields.

Kamforite.—A proprietary fertiliser and insecticide. It is stated to supply nitrogen, phosphoric acid, and potash to plant life, in addition to destroying insect pests, and to be suitable for farms, gardens, and nurseries. It is sold in Holland under the name of Carboniet, where it is stated to be useful in farming and in bulb-growing.

Nitrogenina or Soluble nitrogenous organic fertiliser.—A commercial fertiliser stated to contain animal material (skin, bones, and blood), rendered soluble by a special process. An analysis gave 3·5 per cent. of nitrogen insoluble in water, and 2·5 per cent. of nitrogen soluble in water and 0·16 per cent. of ammoniacal nitrogen.

It is an easily decomposable powder, but its fertilising action is less rapid than dried blood.

Phosphazote or Phospho-nitrogen.—Calcium cyanamide is converted into cyanamide by treating a suspension of it in water with carbon dioxide

$$CaCN_2+CO_2+H_2O=CaCO_3+CN_2H_2 \text{ (cyanamide)}$$

The solution is filtered to remove the calcium carbonate and when the concentration of the cyanamide has reached

a certain point sulphuric acid is added, when the following reaction takes place.

$$CN_2H_2+H_2O=CO(NH_2)_2 \text{ (urea)}.$$

The solution is then treated with calcium phosphate, which gives a fertiliser containing soluble phosphoric acid and urea, known commercially as Phosphazote. It contains no free acid and does not cake. The material does not deteriorate in bags, and is easier to handle than superphosphate.

Superam.—A fertiliser obtained by the treatment of superphosphate with dilute gaseous ammonia (3–5 per cent.), which combines partly with the free phosphoric acid, and partly with the phosphoric acid of the monocalcium phosphate.

If 100 kilograms of superphosphate (16–18 per cent.) is acidified with 10 kilograms of sulphuric acid, then treated with dilute gaseous ammonia, 110 kilograms of superam are produced, containing 4·1 per cent. of nitrogen, and 15·8 per cent. of total phosphoric acid, of which 97 per cent. is easily available, and 76 per cent. is soluble in water.[1]

Sulphurophosphate.—A French phosphatic fertiliser supplied in different strengths phosphoric acid, from 14–28 per cent.

Its fertilising properties are similar to those of superphosphate, and it is prepared by the combination of raw mineral phosphate with superphosphate. It can be used in mixed fertilisers and can be mixed with calcium cyanamide.

Zeotokol.—A coarsely grained basaltic dolerite, finely ground for use as a fertiliser.

[1] *Chimie et Indistrie*, August 1923.

Zeonite.—A fertiliser consisting of inert material with a manganese salt, and giving about 40 per cent. of manganese dioxide.

Seeds treated with a 0·1 per cent. solution of manganese sulphate for six hours showed 6 per cent. greater germination than the untreated seeds.

Miscellaneous Fertilisers

Among the materials which are stated to have fertilising value, and yet are not recognised as actual fertilisers, because they do not contain nitrogen, phosphoric acid, or potash, are those which are applied to the soil to improve it, or to render the plant food more available. In a broad sense, they might be considered as fertilising materials in that they do, under certain circumstances, increase the yield of crops.

Some of them are frequently referred to as catalytic fertilisers, because they are supposed to aid plant growth by accelerating the natural soil processes.

Sulphur does, under certain conditions, influence plant life, and appears to favour ammonification, and salt, sodium sulphate, and gypsum have value in particular circumstances.

Salt.—This material is often valuable on land which is known to benefit by the application of kainit, and it is moderately useful for plant life in rendering the potash in the soil more available for the plant. It has its greatest effect on chalk soils, and on land affected by "club-root."

It is recommended for vegetables, but is especially valued for mangolds, and has given an increase of 20 per cent. with this crop, using from 4–6 cwts. per acre. It is

applied in top dressings, in addition to application in drills with the seed.

Salt has also been known to give good results with cereals and grass. It has also been effective in destroying weeds.

On the other hand, salt gives rise to an alkaline reaction in the soil, and to some extent spoils the tilth of the land. Except for mangolds and a few other crops, it is not required, as the soil usually contains sufficient amount, from that brought down in rain, and from the manure of cattle which have been fed on salt lick.

Potatoes do not do well with salt, probably due to the chlorine radicle, and for the ordinary purposes of rendering the potash more available, it would appear to be better to apply the sulphate, as this is known to give good results.

The addition of salt in some circumstances may give an increase in yield but the expense of distribution hardly justifies it.

It can be mixed with lime, but not with superphosphate or potassium sulphate.

Sodium sulphate.—This compound is stated to have fertilising value, and there is evidence to show that it frees the potash already in the soil. It has no bad effects, but should be free from acid. It has given good results at Rothamsted.

Gypsum or Land plaster.—Gypsum is made by the action of sulphuric acid on limestone, and also occurs naturally and is mined.

The mineral variety contains from 90–95 per cent. of calcium sulphate, 3–5 per cent. of calcium carbonate, and 1–2 per cent. of silica.

It has been found to give good results when applied to clover and turnips.

Gypsum is not used much as a fertilising material as superphosphate contains it in considerable quantity. Its action in improving the soil is probably due to the liberation of potash by it, from the double silicates of potash in the soil.

It has value in the presence of rapidly decomposing organic matter, as it prevents the too rapid formation of ammonium carbonate, whereby nitrification is slowed up, by fixing it as ammonium sulphate. It is used to dry superphosphate, and to repair the injury to tilth of soil caused by excessive use of sodium nitrate. If superphosphate is used, its application is generally unnecessary.

Manganese fertilisers.—These fertilisers usually consist of manganese sulphate, and it is stated that the application of 50 lb. or more per acre increases the yield of oats 20 per cent., rice 30 per cent., and barley, wheat, peas, beans, and carrots similarly.

Sulphur.—It has been stated that the application of sulphur to the soil has resulted in an increase in the yield of vegetables, potatoes by 15 per cent. and turnips by 30 per cent. It has also given higher yields with tomatoes.

It increases the starch content of vegetables, and it has no effect upon the germination of barley.

The use of sulphur has given an increase in the amount of water-soluble potash and calcium, and when applied to leguminous plants, it has been found that these plants contain more protein.

About 40 lb. per acre has been found to be a satisfactory amount. It must be remembered that sulphur lowers the P_H value of soils and leaves them acid.

Comparatively little work has been done with sulphur, and the study of its action on the soil and crops is more or less in the experimental stage.

Silicates.—In pot experiments, soluble silicates, such as permutite, have been found to induce a stronger growth and a greater consumption of plant food from the soil.

Lime-kiln ashes.—These ashes, obtained by burning lime with wood, usually contain only 1·5 per cent. of potash and 1 per cent. of phosphoric acid, and therefore have little fertilising value.

Destructor refuse.—This product does not appear to have any fertilising effects, but it has value in improving the mechanical condition of the soil.

Coal ashes.—These ashes as a rule contain less than 1 per cent. of potash, and have no fertilising properties, but have a mechanical effect upon heavy soils.

CHAPTER X

LIME

No method of improving the soil other than fertilising or cultivating it, is so important as liming or chalking. It has long been established that a regular dressing of lime is necessary for all crops, and although this substance is not usually regarded as a direct fertiliser, its function is so important, that it must be looked upon as a valuable soil improver.

Its presence tends to govern the efficiency of true fertilisers, in addition to being a plant food in itself.

The use of lime in the past has apparently been much more universal than at the present time, and in consequence many soils now lack this essential constituent. It is possible for the land to be so short of this material that fertilisers give a poor return unless lime or chalk has been previously added.

The reason that this constituent is now considerably depleted in certain soils, is that chalk is not a permanent component, but is slowly dissolved out of the soil by water charged with carbon dioxide, and is washed out in the drainage water.

The loss of lime by this means can be very considerable, and may range from a $\frac{1}{4}$ to $\frac{1}{2}$ ton per acre per year. Sulphate of ammonia applied as a fertiliser is responsible for some loss of lime from the soil. It does in fact remove

about half its own weight of chalk. Superphosphate, kainit, and potassium sulphate do not increase the loss to any extent, and organic matter such as farmyard manure tends to decrease the loss of chalk from the soil. Basic slag also has a tendency to reduce the loss. Generally, however, the losses can be considerable, and regular applications of lime or chalk should be made to retain the fertility of the land.

One of the chief functions of lime in the soil is to overcome sourness. A soil deficient in lime will become sour, and the decay of organic matter incomplete, because the bacterial activity is decreased, due to the formation of peaty material, acid in character. The process of nitrification, one of the most important for the production of plant food, is retarded by this sourness due to lack of lime. The process of the breaking down of humus, and the formation of nitrates is increased by the addition of lime, from the fact that the acids produced in the decay combine with the basic lime. The bacteria in the soil are essential to the life of plants, and these micro-organisms are very susceptible to a change in their surroundings. The type which flourish in a neutral medium will become inert in an acid one, and if lime is deficient and is not added, the activity of the bacteria will be decreased. Under these conditions, the process of nitrification will be slowed up, and fertilisation impeded.

Lime also improves to a large extent the condition of the soil, especially of clay soils, which show the greatest benefit in tilth by the application of lime, in that it renders them more open and porous, and less subject to shrinkage and caking, and more easily worked.

The amount of lime in clay soils should be at least 0·5 per cent. Lime has marked effects upon the mineral

constituents of the soil, in that it breaks down the insoluble potash salts, replacing the potash, and leaving this substance available as plant food. To some extent it also liberates phosphoric acid from the soil. It reduces the "finger and toe" disease in turnips, and "club root" in cabbages, and 2 tons of ground lime or $3\frac{1}{2}$ tons of ground limestone per acre are stated to be suitable quantities for this purpose.

Lime is also advocated as a preventative of "clover sickness." Certain crops respond readily to the presence of lime in the soil, and leguminous crops, sanfoin, and clover, as well as turnips and barley, do well with ample supplies of lime. Potatoes respond less than any crop to lime dressings, and in the case of "corky scab" diseases it is best withheld altogether, as the micro-organisms which cause this disease thrive best in an alkaline soil.

Lime is also used in orchards where fruit trees are affected with "crown gall."

The application of lime to the soil tends to reduce certain weeds and insects, and heavy dressings of it, together with sand, are often applied to peat and bog soils to recover them for crop production.

Lime is not a substitute for manure, and should not be mixed with fertilisers of any kind before application to the soil.

The effect of lime will last for some time, and the application of from 1–2 tons per acre will last for several years.

Quick or burnt lime, CaO, is the most common form of lime used, and is obtained by burning chalk or limestone in a kiln. If it is kept and exposed to the action of the atmosphere, it reverts back to the carbonate again, with, of course, a loss in value, as the carbonate is cheaper.

Lime possesses an advantage over chalk, in that when it is spread over the land it breaks down naturally into very fine particles, which are easily carried into the soil and its action more quickly felt. Quicklime is sometimes slaked first, put on to the soil immediately, and harrowed in.

Ground lime is a quicklime ground to a powder. It is often not so pure as lump lime, but should contain from 70–75 per cent. of CaO. As lump lime slakes so easily, it is not always an advantage to pay the cost for the ground material.

Ground limestone consists of an unburnt limestone ground to a fine powder. Its action on the soil is not so rapid as quicklime, and it probably does not have the same action upon clay. It has, however, many advantages, among which is the ease with which it can be handled, the uniformity of its distribution, and the fact that it can be stored if the weather is unsuitable for its use. This last is important, for burnt lime will soon deteriorate and destroy the bags containing it. The equivalent of 1 ton of best burnt lime is $1\frac{3}{4}$ tons of ground limestone.

Chalk is a soft limestone, which is generally pure calcium carbonate. It is usually applied in lumps during the winter, when it is broken down, and harrowed in in the spring. It is an economical form of lime, for it can be used for smaller and more frequent dressings. Based upon the actual lime contained in chalk, this material should not cost much more than half that of burnt lime. The ground material costs a little more.

Waste lime products.—Certain industrial processes, such as those carried out in soap, soda, paper, coal gas works, bleaching factories, and sugar refineries provide waste substances consisting mainly of calcium carbonate (chalk) in a very finely divided condition, with smaller amounts

of other products such as caustic soda and sodium carbonate, all of which are basic in character.

Some contain other impurities, often harmful ones, and all these products should be used with care.

The waste materials from soap, paper, and bleaching factories usually contain from 30–40 per cent. of water, but as sources of lime they are valuable in that when dried, they may contain as much as from 60–90 per cent. of chalk, and have been shown to be effective in "finger and toe" disease.

Generally from $2\frac{1}{2}$–3 tons of the wet material or $1\frac{3}{4}$–2 tons of the dried product are equal to 1 ton of burnt lime.

Lime from sodium carbonate in the Leblanc soda process.—At one point in this process the sodium carbonate is treated by boiling with lime, when caustic soda and chalk are produced.

The chalk washed free from alkali and dried, can be applied directly to the soil. It contains on an average from 60–80 per cent. of chalk in a good physical condition.

Lime from magnesium carbonate waste.—When magnesium carbonate is made from magnesium limestone by ignition, then treated with water and carbon dioxide under pressure, the magnesium bicarbonate is separated from the insoluble chalk. This chalk is practicaly free from magnesia, and is suitable for application to the soil.

Chance mud or Lime mud.—This material is the mud left after the treatment of alkali waste with carbon dioxide to remove sulphur. It contains approximately 33 per cent. of chalk, and is used for agricultural purposes.

Lime sludge from sulphate-pulp manufacture.—This waste product is stated to be good for liming the soil, and the dry material contains from 69–90 per cent. of chalk,

2–11 per cent. of calcium hydrate, 0·3–1·67 per cent. of calcium sulphate, and 7·5–21·5 per cent. of silicate.

Waste from sugar works.—The sludge obtained from the filter presses in sugar manufacture is a source of lime. The waste lime from beet sugar factories contains roughly 36 per cent. of chalk, 8 per cent. of organic matter, and 45 per cent. of water.

Small lime, screenings, and small chalk.—These are forms of waste lime suitable for use in agriculture.

Burnt sewage.—This is a good form of waste lime, usually containing more than 60 per cent. of lime.

Gas lime.—Lime is used in the purification of coal gas to remove the sulphuretted hydrogen and carbon disulphide from the gas, by passing it into chambers containing slaked lime.

The waste lime consists of slaked lime and sulphur compounds, and varies considerably in its composition. Fresh gas lime contains calcium sulphide, sulphite, thiocyanate, and hydrate, with smaller quantities of ammonia, cyanides and ferrocyanides. Some of these compounds are toxic to plants, therefore the fresh material is unsuitable for use for liming.

Exposure to rain and the atmosphere oxidises the sulphur compounds to sulphates, and it is best only to apply it to the land after this oxidation.

Basic slag.—This material usually contains 45 per cent. of lime, some of which is in the basic form, and capable of curing acidity of soils as well as giving phosphorus as a plant food. It contains about 2–5 per cent. of free lime.

Acetylene gas by-product.—When acetylene gas is prepared from calcium carbide, slaked lime is produced with from 30–40 per cent. of water. The dry material contains 60 per cent. or more of lime, CaO. This product

must be used with caution as the fresh substance often contains toxic materials. It should, therefore, be applied only after it has been exposed to the weather, thereby rendering the poisonous substances harmless.

Waste tannery lime.—This is another waste product which often contains sulphides which are injurious to plant life. It should be exposed to the atmosphere before use.

All these waste materials should be bought only after analysis, and should be low in price.

Lime requirements of a soil.—More cases of crop failure are due to a deficiency of lime than a shortage of plant food.

The lime requirements of a soil will depend upon the type of crop grown, and other factors, and is not identical with the amount of lime needed to bring the soil to neutrality.

It does not bear a precise relationship to the H-ion concentration, which is only a measure of the intensity factor of soil acidity, and the amount of base required to bring about the neutral condition will depend upon the strength of the acid, and the extent of buffering in the soil.

There is, however, usually a general interdependence between the H-ion concentration and the amount of lime required.

In addition to acidity and the presence of aluminium and magnesium salts, indications that a soil needs lime are when certain weeds such as mayweed, spurrey, sorrel, beggar-weed, sand-weed, corn marigold, bracken, and gorse are prevalent, and the application of lime will reduce these weeds.

Lack of lime also results in the absence of clover, and an excess growth of bent grasses. The repeated failure of the clover crop, the presence of the " finger and toe "

disease in turnips, and the lack of response to treatment by fertilisers, is a guide to the lime requirements.

The fact that *Azotobacter chroococcum* will not grow in a medium with a P_H value lower than 6·0 has been used as a basis of measuring the lime requirements of a soil, and this method has been applied in Denmark.

A method stated to give good results consists in taking 50 grams of the soil in a 100 c.c. stoppered cylinder. Measure 30 c.c. of a saturated solution of potassium thiocyanate in 95 per cent. alcohol (P_H=5·3), and pour it over the soil. Stopper the cylinder and shake for two minutes. Allow to settle. If the colour of the supernatant liquid is pink, add 0·1 normal alcoholic potash, shake and allow to settle. Let it stand some hours and again titrate. If too much base has been added, titrate back with 0·1 normal alcoholic acid. Each c.c. of 0·1 normal base used= 200 lb. of chalk per acre.[1]

Detection of aluminium.—A few drops of an alcoholic solution of logwood added to the potassium thiocyanate extract of the soil indicates the relative amounts of aluminium by the depth of colour.

Lime and fertilising.—The continued use of ammonium sulphate, without lime, over many years, results in the soil becoming so acid as practically to inhibit growth. Heavy applications of farmyard manure tend to correct the unfavourable condition brought about by the continued use of this fertiliser without lime.

The presence of lime in the soil allows a more efficient utilisation of soil nitrogen, and of that contained in the fertiliser. The application of superphosphate cannot replace lime in the soil, as it is the basic action of the latter which is its most valuable property.

[1] R. H. Carr, *Ind. and Eng. Chem.*, vol. xiii, p. 932, Oct. 1921.

Although lime is so necessary, and generally increases crop production, it must be remembered that it is not a substitute for fertilisers, and it should not be mixed with fertilisers of any kind. The best effects of lime are realised after a year or two.

Too heavy or too frequent dressings of lime are harmful, as they exhaust the stores of nitrogenous materials contained in the soil. Lime is converted into carbonate, and then into bicarbonate in the soil, and is then carried away in solution.

The residual effects of 40 years' continuous fertiliser treatment, and the fate and physical effects of applied lime have been described by J. W. White and F. J. Holben.

In the 40 years' period, 35,200 and 41,754 lb. of lime were applied as lime and ground limestone respectively. In the limestone treated soil 17,631 lb. of the carbonate was decomposed (63 per cent. from manured and 61 per cent. from unmanured plots).

Of the lime 12,906 lb. were lost from the surface soil, and of this 60 per cent. was lost by being carried into the subsoil, 6·5 per cent. was removed by crops, and 33·5 per cent. was lost by drainage.

When applied as limestone 5,407 lb. or 13 per cent. was lost from the surface soil, of which 64·5 per cent. went to the subsoil, 10 per cent. was used by the crops, and 25 per cent. was lost by drainage.

A plot fertilised with ammonium sulphate decomposed calcium carbonate twice as fast as an untreated plot.

The average P_H value of the plots receiving burnt lime and ground limestone for 40 years was 7·88 and 7·68 respectively.

The burnt lime plots contained an average of 64·7 per cent. more nitrates than the unlimed check.[1]

[1] *Soil Science*, **22**, 61–74 (1926).

Application of lime.—The operation of liming should be performed so as to get the most intimate mixture with the soil. This implies fineness of division in the form of lime to apply, and this is a very important matter.

Quicklime has a more energetic action than chalk, due to its solubility, producing a more uniform distribution throughout the soil before precipitation as carbonate occurs.

One method is to slake the lime with water, immediately putting the slaked product on to the land. This method is only good for the best or "fat" limes, which readily slake to a fine powder. One of the best methods is to put the lime on the land in heaps, and cover these with soil, when the lime gradually breaks down to a fine powder, and can be distributed when ploughing.

Lime varies considerably in its purity. Good samples of burnt lime should contain 90 per cent. or over of CaO.

White, "fat" limes slake well, and make a fine powder. Thin limes slake poorly, and set in hard lumps.

Grey lime contains on an average 75 per cent. of CaO.

Slaked lime is sold very pure, and in a fine state of division.

Ground lime is a very useful form to apply, in that it can be distributed evenly, and several small dressings of this are better than a larger dressing. It cannot be kept in bags for more than a week or two, as these will become rotten.

"Seconds" lime is the residue left after the best lumps have been selected. It is usually good for the purpose of liming, unless it contains much foreign matter.

Burnt lime is most suitable for arable land, and in the treatment of clay and peaty land. It has insecticidal properties, and exerts a direct action upon the organic

matter in soils. Burnt lime should be used with caution, and should not come in contact with growing crops.

Ground limestone, if very finely ground, gives good results, and from the fact that it can be easily handled, distributed, and stored, has some advantages over lime.

Chalk may be used in the place of lime with advantage when it is more readily obtainable. It requires $1\frac{3}{4}$ tons of chalk to supply as much lime as 1 ton of burnt lime, and the decision which to use will rest not only upon price but upon the merits of each individual case, the cost of transit, cartage, and distribution. On lighter soils, ground chalk or limestone is more suitable than lime, as there will not be so much danger of excess as with lime. Limestone dust, which is obtained when limestone is quarried, if cheap, is a useful material for some soils. It is often obtained from magnesium limestone rocks, and contains this material. Stones and pieces of rock are also present.

Lime from magnesium limestone.—This material often contains from 50–80 per cent. of lime, and from 4–40 per cent. of magnesia. It is used with advantage on some soils. The magnesium oxide is generally considered harmful and is certainly not so suitable as lime. This is due to the fact that bases in the free state are injurious to vegetation, and magnesia combines less readily with carbon dioxide, and therefore magnesium hydroxide is present in the soil for a considerable time.

Magnesium lime is not recommended for thin or light sandy soils, but has given good results on soils of the peat type, or very heavy soils known to be sour. It is never preferable to lime.

Amounts of lime to use.—For normal soils, the amounts of lime required are stated to be from $\frac{1}{2}$–1 ton of burnt lime or 1–2 tons of chalk per acre in four or five years, but

for acid or sour soils more may be required, and more frequent applications. More is also needed for heavy or wet lands, but less for light soil.

If the soil is known to be sour, the lime should be applied as long a time as possible before the next crop. Land that has laid wet during the winter should have lime given in the spring.

For normal soils a light dressing is applied before sowing, and harrowed in at once. In breaking up old grass land, the lime is applied before or after sowing.

The value of limestone and chalk mainly depends upon the fineness of division, and are preferable materials for use on sandy soils poor in organic matter. They can be applied at any time during the year, but the action takes some time to function. They are valuable for grass land as they do not burn.

Lime should be put on to the soil some time before the application of fertilisers, otherwise chemical action between the fertiliser and lime may take place, and impair the efficiency of both materials. The prices of lime materials ruling in November, 1926, in London were as follows :—

Burnt lump lime, £2 1s. per ton.
Ground lime, £1 15s. per ton.
Ground limestone, £1 10s. per ton.
Ground chalk, £1 5s. per ton.

Rotation Crops and Fertilising

The method of rotation cropping is extremely practised, and often results in a considerable saving in the use of fertilisers.

If only one class of crops is grown without change, a

diminished return will often follow, whereas, if a suitable rotation of crops is chosen, the plants will be more abundant, and of a finer quality.

The diseases which affect certain crops grown on the same land year after year, can often be prevented by this system, and the risks of insects and fungoid pests reduced.

It assists in the destruction of certain weeds which favour one crop more than another. This is especially the case when root crops follow cereals.

It ensures the full use of the whole range of plant foods in the soil, as one group of crops will make different demands to another upon the soil. Some plants, such as cabbage, require potash and nitrogen, and if followed by a leguminous crop, which require phosphates particularly, and also actually restore nitrogen to the soil, a saving in fertiliser is secured, and the soil is kept in a balanced condition. Winter greens always require nitrogen, and farmyard manure or other nitrogenous fertiliser is good. Potatoes, if following, do not require much nitrogen.

Plants of different types improve the soil, in that they have different habits of growth, and require different modes of cultivation.

Deep-rooted plants, such as wheat, can follow shallow-rooted ones, as barley or oats, to make use of all the resources of food in the soil.

All plants do not exhaust the soil to the same extent, for plants which are cut green do not consume so much food as plants required for fruit or seed.

In the choice of a particular rotation, the climate plays an important part, for oats, turnips, and forage crops do well in a cool moist climate, but cereals require drier conditions.

The type of soil must also be considered, as clay soils

are good for wheat, beans, cabbage, and mangolds, and chalk soils are poor for potatoes and oats, but good for clover and peas.

Labour conditions, and the demand for particular crops, must also be considered in the choice of a rotation of crops.

In the fertilisation of rotation crops, the fertilisers are not all applied to one crop, and it is not necessary to give every crop plant food. It is usual to apply farmyard manure to the most important crop, using artificial fertilisers on the succeeding ones.

A 2-course rotation might consist of wheat and beans, and a 3-course one of fallow, wheat, and beans. In such a rotation as the Norfolk 4-course, which usually consists of turnips, barley, clover, and wheat or oats, farmyard manure is applied to the first crop, with superphosphate and ammonium sulphate, and sometimes on light land some potash. The second year's crop will not need fertiliser at all, but a catch crop of rye or clover is sometimes sown, and when the barley is removed is fertilised with superphosphate, potassium chloride, and ammonium sulphate. The third year's crop, clover, requires a small amount of ammonium sulphate, and the fourth year's wheat crop needs some superphosphate.

There are many varieties and modifications of rotation crops, and the choice will rest upon the type of soil, the climate, and the demand for the crops. The greater the variety the better, but the demand, whether for the needs of live stock or for roots, potatoes, or cereals, must be studied.

In choosing a vegetable rotation, the demands of certain plants for particular fertilisers must be considered. Among the crops which require chiefly phosphate and potash, are potatoes, beans, and peas. Those which do well with a

main food of nitrogen and phosphate, are cabbage, sprouts, and cauliflower.

Crops which mainly depend upon nitrogen and potash are beet, carrot, parsnip and radish; and plants which require all are onion, leek, turnip, celery, and fruits.

Therefore a suitable vegetable rotation would be:—

1. Potatoes.
2. Beans and peas.
3. Cabbage, cauliflower or sprouts.
4. Beetroots, carrots, parsnips, onions, turnips, or celery.

For fertilising purposes, farmyard manure is used supplemented with artificials to suit each crop.

CHAPTER XI

APPLICATION OF FERTILISERS

UNIFORMITY of distribution of any fertiliser is highly important. In the case of very bulky fertilisers such as farmyard manure, seaweed, and others of a similar type, large dressings are required—ten, twenty, and even forty tons are not unusual—and it is difficult to distribute these very carefully, but with the more costly artificial fertilisers, it is highly important that they should be ground very finely and should be dry, and these conditions govern to some extent the choice of a particular fertiliser. If the material is lumpy, it pays to break it up and sieve it before application. The presence of lumps is wasteful, in that all the land does not receive its fair share, and harmful because a concentrated fertiliser will often kill young plants in contact with it.

Sodium nitrate and ammonium sulphate are apt to be lumpy, and must be broken up before use.

Basic slag is usually in a very fine condition, 80 per cent. of it capable of passing through a No. 100 sieve.

Superphosphate is sometimes sticky.

Steamed bone flour should be in an extremely fine condition for use.

Rock phosphate should contain 80 per cent. of material which will pass through a 100-mesh sieve.

Bone meal should be fine and free from grease.

Dissolved bones are apt to be lumpy, as also are potash manures, and if the latter are kept for long, they will often set hard, and become unsuitable for use.

Artificial fertilisers can be distributed either broadcast, or by special fertiliser drills. Generally, separate applications for each fertiliser would be best for their utilisation, but they are often applied mixed to save trouble.

In the application of fertilisers, it must be borne in mind that, of the many varieties which contain nitrogen, phosphoric acid, and potash, these foods are not all available at once, and availability varies considerably. Among the nitrogenous fertilisers, sodium nitrate is a little quicker in its action than ammonium sulphate, and superphosphate is more rapidly effective than phosphate rock.

Sometimes one type is more suitable for a particular crop. It appears that for corn, grasses, and turnips it does not matter whether the potash is in the form of chloride or sulphate, but for sugar beet, potatoes, and tobacco, the sulphate is to be preferred, as the chloride is stated to reduce the sugar content of beets, to give a tendency to waxiness in potatoes, and to cause the tobacco leaf to burn badly.

Basic slag is especially useful for pastures and meadows.

Too little fertiliser is wasteful, and too much harmful.

Time of application of fertilisers.—All artificial nitrogenous fertilisers are liable to loss, as nitrates are easily washed out of the soil, therefore they are usually applied either just before the crop is up, or when it is above the surface. Sodium nitrate is applied mostly as a top dressing after the crop is up, and ammonium sulphate just before the crop is up, or as a top dressing after.

Insoluble organic manures should be put on before or during the winter, and liquid manure in the spring.

Superphosphate is often sown with the seed, especially

for swedes and turnips, but for more deeply-rooted crops such as hops and fruits, it is best applied in the winter or early spring.

Basic slag should be applied in the winter or even in the autumn, as there is little risk of loss.

Potassium sulphate is best sown with the seed as there is some loss with rain, but kainit can be used as a winter dressing, as there is only small losses of potash.

Fertilisers for particular soils.—Light soils are usually low in potash, sometimes in lime and phosphate, due to their rapid drainage. The fertilisers likely to be needed are superphosphate, ammonium sulphate, and potassium sulphate or kainit. Farmyard manure is essential, as it increases the retaining power of the soil, and spreads the water supply over a longer time.

Ammonium sulphate and sodium nitrate also do good to these soils when they lack water. The soluble fertilisers such as superphosphate and potash salts have proved most useful, and if there is a deficiency of lime, basic slag is better than superphosphate. Lime is easily removed from these soils and needs replacement. Sodium nitrate has been found to be not so good as ammonium sulphate on light soils, and calcium cyanamide is also a good fertiliser for this type of land.

Superphosphate is a favourite phosphatic fertiliser for light land if the soil contains a moderate amount of lime, and basic slag is also good, but must be put on earlier.

Clay soils are generally poor in lime and phosphates, but are usually fairly well provided with potash and organic matter. For the improvement of this type of soil, methods of good cultivation, and the application of lime and phosphates are the most important. Basic slag is a good phosphatic fertiliser for heavy soils.

Chalk soils are improved by the use of superphosphate, ammonium sulphate, and potash. Farmyard manure and all the artificial fertilisers do well on this soil.

Peaty soils require lime and phosphatic fertilisers, and basic slag is a useful phosphatic one. Ammonium sulphate is valuable as a top dressing after liming.

With wet soils, top dressings of artificial fertilisers are better than applications of farmyard manure, and land in this condition generally requires phosphatic fertilisers.

In cold conditions, it has been demonstrated that stimulating fertilisers are necessary, and phosphates and ammonium sulphate are suitable ones to apply. Lime may also be needed.

Fertilisers for Particular Crops

The application of fertilisers to a particular crop will depend upon the place it occupies in the rotation; root crops generally require dung and complete artificial fertilisers, the succeeding cereal crop responds to a little more nitrogen for wheat or oats, or super for barley, and seeds may require lime, basic slag, or potash.

The resources of food in the soil, the type of soil, and the methods adopted in cultivation, also play a part in the application of fertilisers.

If the supplies of one fertiliser are difficult to obtain, or the price of it is prohibitive, or the cartage too dear, others may replace it.

Basic slag can replace superphosphate, and steamed bone flour may be used instead of either superphosphate or basic slag.

Rock phosphates of good quality can be used if supplies of other forms are not available.

In considering the following list of fertilisers for particular crops, it must be emphasised that it is only a general one for average conditions, and may need modification or adjustment for particular soils and conditions.

Asparagus.—This plant requires a fine porous soil, rich in organic matter, with the application of superphosphate and kainit in the spring. A top dressing of sodium nitrate at intervals improves the crop.

Barley.—Phosphates are essential for a barley crop, and when grown after a root crop, superphosphate should be applied and a nitrogenous dressing. The latter should be small, as nitrogen tends to produce straw at the expense of the grain.

Rape dust is a very suitable fertiliser for barley, as it contains only a small quantity of nitrogen.

If the root crop has been well fertilised, or the roots fed to sheep, no nitrogenous material is necessary, but about 2 cwts. of superphosphate should be applied. Potash is also sometimes needed.

If the soil is poor, or after a straw crop, suitable dressings per acre are 1 cwt. of ammonium sulphate, from 2–3 cwts. of superphosphate or 1 cwt. of superphosphate and 1 cwt. of steamed bone flour, and from 2–3 cwts. of kainit.

On light soils, salt is sometimes applied.

Beans.—As for peas.

Cabbage, sprouts, and green crops generally.—These crops require large amounts of farmyard manure, and also top dressings of artificial fertilisers. The amounts necessary vary from 10–18 tons of dung per acre, with from 3–4 cwts. of superphosphate, and on light land from 2–3 cwts. of kainit. Top dressings of 1 cwt. of ammonium sulphate at the time of planting, and 1–3 cwts. of sodium nitrate

some weeks later, give good results. Salt is often good for these crops, especially cabbage on light soil. When cabbages are slow to heart up, there is probably a deficiency of phosphate.

Carrots.—As for parsnips.

Celery.—It has been demonstrated that this plant requires phosphates and potash, and superphosphate and potassium sulphate are suitable materials to apply. If dung has been used, no nitrogenous fertiliser is necessary, but if on poor light soil, sodium nitrate is good. Excess of nitrate produces poor stems.

Clover.—In a similar way to other leguminous plants, this crop assimilates nitrogen, and requires no nitrogenous fertiliser. Phosphates and potash are needed, but heavy soils do not often require potash as considerable supplies are already present, and may be released by the application of lime. It is for this reason that basic slag is so beneficial to this crop. Basic slag and kainit on light soils give good results.

Cucumbers.—These require a rich soil, and superphosphate and ammonium sulphate are useful materials for stimulating the growth.

Currants.—These bush fruits usually require basic slag and potash in the form of kainit applied in the winter, with a little ammonium sulphate in the spring. On lighter soils superphosphate is better.

Flax.—If grown for fibre, this crop requires potash, and kainit or potassium chloride is generally used at the rate of 1 cwt. of potassium chloride or 4 cwts. of kainit per acre. If nitrogen should be required, rape meal is a suitable form. If the crop is grown for seed, it needs phosphate in addition to ammonium sulphate and kainit or potassium chloride, and from ½ to ¾ cwt. of ammonium sulphate, 3–4

cwts. of superphosphate, and $\frac{1}{2}$ to $\frac{3}{4}$ cwt. of potassium chloride are suitable amounts.

Flowers.—The ground should be manured in the autumn for spring flowers, and the beds for late plants should be manured just before planting. Farmyard manure should be worked in deeply. Flowers generally require phosphate and superphosphate or basic slag are useful forms. Bone meal is also a good material for these plants. Potash may also be wanted.

Carnations do well with superphosphate and sulphate of ammonia applied as a top dressing in the spring. Roses require phosphate, as well as a soil rich in organic matter, and lime put on in the winter is sometimes needed. A spring dressing of ammonium sulphate and superphosphate may be applied, and if special stimulants are needed a liquid manure may be used. Chrysanthemums generally require a complete fertiliser, and ammonium sulphate, superphosphate, and potassium sulphate are generally used. Annuals usually benefit with a top dressing of superphosphate and ammonium sulphate, and perennials do well with basic slag and potassium sulphate in the winter and superphosphate and ammonium sulphate in the spring.

Fruit trees.—Farmyard manure is important for fruit trees, and when they are bearing freely, they should be regularly manured, nitrogen and potash being needed for the development of new growth, and phosphate and lime for the production of fruit of good quality. The extent of the fertilising will depend upon the soil, and upon the circumstances in each case.

As a potash fertiliser, the sulphate is considered best, and not kainit. Phosphate is added in the form of basic slag. Lime is important, and this material, together with

phosphate and potash, should be applied in the autumn or spring. General dressings consist of up to 20 tons of farmyard manure per acre in winter, 3 cwts. of basic slag or superphosphate or bone meal after pruning, and $\frac{1}{2}$–$1\frac{1}{2}$ cwts. of sodium nitrate or ammonium sulphate in the spring or summer.

Gooseberries.—Manuring is similar to that for currants.

Grapes.—This fruit requires mainly phosphate, and in addition nitrogen and potash. Superphosphate is the usual phosphatic fertiliser applied, and ammonium sulphate the nitrogenous one. It is stated that urea has given as good results as the latter. Potassium sulphate or chloride are suitable potash dressings.

Hay.—Phosphates are essential for this crop, and usually potash is also required. Basic slag is by far the most important fertiliser for hay, but superphosphate does well in dry districts. Lime is also valuable and should be applied at the rate of 1 ton of ground lime or 2–4 tons of ground limestone every four years.

The best treatment for hay consists in the application of from 10–12 tons of dung, with 4 cwts. of basic slag per acre, but if no dung is available, a nitrogenous fertiliser is an advantage, but it must be supplemented with phosphate, and on a light soil with potash as well.

Sodium nitrate appears to be somewhat better than ammonium sulphate when used with phosphate and potash. Nitrogen gives bulk to the crop, and phosphate and potash, quality.

For meadow hay, from 10–12 tons of dung every four years, with 1 cwt. of sodium nitrate or ammonium sulphate, and 3–4 cwts. of basic slag per acre, are suitable quantities, and if no dung is used, 1 cwt. ammonium sulphate, from 2–3 cwts. superphosphate, and $2\frac{1}{2}$ cwts. of kainit, are good.

For seeds hay, when clover is scarce, use from 1–2 cwts. of ammonium sulphate or sodium nitrate, and on light soil 2 cwts. of superphosphate. When clover abundant, use from 3–4 cwts. of superphosphate, and from 1–2 cwts. of potassium chloride or sulphate.

Hops.—Complete artificial fertilisers are stated to be better than manure for this plant. The absence of potash and nitrogen delay ripening, and the application of phosphate induces early ripening.

Kohl-rabi.—A cattle and sheep food. It belongs to the cabbage family and is a gross feeder. It requires from 10–12 tons of dung, supplemented with from 4–5 cwts. of superphosphate, 3–4 cwts. of kainit, and 1 cwt. of ammonium sulphate.

Lavender.—As for mint.

Lawns.—Deep, well-drained, rich soil makes the best lawns, and the most valuable fertilisers are basic slag and small amounts of ammonium sulphate. Bone meal and potassium sulphate also benefit lawns.

Alkaline conditions in the soil tend to encourage dandelion, plantain, and other weeds.

Leeks.—As for onions.

Lettuce.—As for cabbage.

Lucerne.—This crop makes large demands upon phosphate, potash, and lime in soils, and these should be present to obtain the best results. Although it is a leguminous crop, and makes use of the nitrogen of the air, it often requires a dressing of ammonium sulphate or other nitrogenous fertiliser. On ordinary soils, sodium nitrate, with dressings of phosphate and potash give good results. On heavy soils, deficient in phosphates, from 4–5 cwts. of a high-grade basic slag per acre give good yields. A top dressing of farmyard manure is good.

Lupins.—This is valuable as a fodder crop, and will grow on poor soils, with from 3–4 cwts. of superphosphate, and from 2–3 cwts. of kainit per acre. Gypsum also is an advantage on poor soils. Lupins assimilate and store up nitrogen, and are used sometimes for green manuring.

Maize.—This plant is a gross feeder, and the land must be heavily manured to give the best results.

After a root crop, or with from 10–12 tons of dung, from 1–2 cwts. of sodium nitrate or ammonium sulphate, and from 3–4 cwts. of superphosphate or other phosphate per acre are suitable quantities. Without dung, and on heavy land, 1 cwt. of ammonium sulphate, 3 cwts. of superphosphate, and 1 cwt. of sodium nitrate later, should be used, and on light land, $\frac{3}{4}$ cwt. of sodium nitrate, 3 cwts. of superphosphate, 3 cwts. of kainit, and $1\frac{1}{4}$ cwts. of sodium nitrate later, are suitable amounts.

Mangolds.—This crop responds to liberal fertilising, and requires large amounts of nitrogen. Potash is also necessary, but phosphates are of less importance. The best results are obtained with farmyard manure in conjunction with artificial fertilisers. Suitable amounts are from 10–20 tons of dung, $1\frac{1}{2}$ cwts. of ammonium sulphate, from 2–5 cwts. of superphosphate or basic slag or $1\frac{1}{2}$ cwts. of fish guano, from 3–5 cwts. of kainit or 1 cwt. potassium chloride, and from 2–5 cwts. of salt, especially if kainit is not used.

If no dung is used, from $1–1\frac{1}{2}$ cwts. of ammonium sulphate put in with seed, $1–1\frac{1}{2}$ cwts. of sodium nitrate applied as a top dressing, $2\frac{1}{2}$ cwts. of superphosphate, 6 cwts. of kainit or $1\frac{1}{2}$ cwts. of potassium chloride, and from 3–5 cwts. of salt per acre, are suitable amounts.

Mint and lavender.—Nitrogenous fertilising give high yields with mint. The highest yields of lavender oil and

flowers have been given with sodium nitrate, and next in order follows ammonium sulphate, complete fertiliser, and superphosphate. Potassium sulphate decreases the yield.

Peppermint, grown for its essential oil, responds to the application of fertilisers, and farmyard manure, with potash, ammonium sulphate, and superphosphate, give the best results. A top dressing of sodium nitrate in the spring speeds up the opening of the leaf.

Mustard.—As for rape.

Oats and rye.—As oats usually follow seeds in rotation cropping, this crop does not often require much fertiliser on a good soil. If fertilising appears necessary, or the soil is poor, or the crop is a winter one, 2 cwts. of kainit, from 2–3 cwts. of superphosphate or basic slag, and 1 cwt. of ammonium sulphate or sodium nitrate applied as a top dressing later, are suitable amounts.

A mixture of 1 cwt. of ammonium sulphate and 3 cwts. of superphosphate, applied immediately after mixing in advance of the drill, is of great benefit on soils poor in plant food.

Onions and leeks.—If no farmyard manure has been applied, 1½ cwts. per acre of ammonium sulphate, with 3 cwts. of superphosphate or steamed bone flour in the early stages should be given, and on light soils salt is good.

Parsnips and carrots.—These plants do best if put into the soil after a crop which has been heavily manured with farmyard manure. No dung should be applied directly to the crop, or the roots will fork. In addition to farmyard manure put on in the autumn at the rate of 15 tons per acre, 4 cwts. of superphosphate or basic slag, or a mixture of steamed bone flour and superphosphate, or a mixture of superphosphate and mineral phosphate, and just before

sowing, about 1 cwt. of ammonium sulphate, should be used. Soot can replace part of the ammonium salt (6 cwts. of soot equals 1 cwt. of ammonium sulphate).

Pasture land.—The primary need for poor pasture land is phosphate. It is usual to apply 10 cwts. per acre of high-grade basic slag, then half this quantity as the need arises for it. Equivalent amounts of low-grade slag or mineral phosphate give good results, and certain finely ground North African phosphate rock is gaining in popularity. Basic slag made with fluorspar is not considered so good.

A deficiency of lime and phosphate is generally indicated by poor land, and the need for lime is usually most marked on heavy soils and in wet districts.

On poor clay soils, basic slag gives marked improvement, and 10 cwts. per acre is usually applied over three years, in the winter. On heavy soils, generally only phosphates are required. On thin soils, basic slag has given good results, and bone meal, fish meal, and meat meal have also benefited pasture land. Potash is useful on light soils, and if phosphates do not give results, it is probably due to lack of this fertiliser. Chalk soils require superphosphate ammonium sulphate, and kainit.

If land responds to basic slag, 5 cwts. per acre every three years is a suitable quantity, and if the soil is unsuitable for slag, from 3–4 cwts. of superphosphate, and 2–3 cwts. of kainit every three years should be applied.

It has been recently shown that grazing land required for intensive culture, benefits greatly by the application of a nitrogenous fertiliser in the spring as a top dressing. Small enclosures receive phosphate and potash in the autumn, and nitrogen in the spring, and the cattle are moved from one enclosure to another. It is claimed that,

by this method, a greater number of stock can be fed, and that the young grass has higher feeding value.[1]

Peas and beans.—The most important constituents of a bean manure are phosphate, potash, and lime. Peas and beans do not require much nitrogen, especially if farmyard manure has been used.

Basic slag has been found good, and steamed bone flour has also proved beneficial for these crops.

Peas or beans should not be given excess of nitrogenous fertiliser, as they will produce much haulm at the expense of the seed.

Suitable amounts of fertiliser for these crops are from 3–5 cwts. of superphosphate or basic slag, and from 1–2 cwts. of potassium chloride or sulphate at time of drilling.

If the soil tends to sourness, basic slag is better.

Potatoes.—The best soil for this crop is a well drained, warm one, rich in nitrogen and potash, and it is best grown on land which has been heavily manured for a previous crop of cabbages, or similar plants. Farmyard manure is good if ploughed in during autumn, but dung supplemented with artificials usually gives the best results. The following are suitable quantities. From 10–15 tons of dung, 1–1½ cwts. of ammonium sulphate, 3–4 cwts. of superphosphate, and 1–1½ cwts. of potassium sulphate. If dung is not used, the artificial fertilisers must be increased by 50 per cent.

Lime is to be avoided for this crop, as it encourages the potato scab disease. Generally ammonium sulphate and superphosphate are to be preferred to sodium nitrate and basic slag, owing to the alkaline conditions which may be set up by the latter.

[1] *Journ. of Min. of Agri.*, Sept. 1926.

Too much nitrogenous fertiliser is not good, as an excessive growth of haulm will be produced.

Rape and mustard.—These crops, which are generally fed off by sheep, require no farmyard manure. They do best with from 2–5 cwts. of basic slag or superphosphate, and $1\frac{1}{2}$ cwts. of sodium nitrate or ammonium sulphate. The phosphate increases the feed-value, and the nitrogen the bulk of the crop.

Raspberries.—This fruit mainly requires phosphate and potash, and fish guano is also a useful fertiliser to apply.

Rhubarb.—This plant is a gross feeder, and up to 40 tons per acre of farmyard manure on heavy soils can be applied during autumn. On the lighter soils, it should be put on some time before planting. Ammonium sulphate at the rate of 2 cwts. per acre is put on in the spring. Every third year, 4 cwts. of superphosphate, 1 cwt. of steamed bone flour, and 2 cwts. of potassium sulphate should be applied.

Rye.—As for oats.

Sainfoin.—Basic slag, up to 10 cwts. per acre, is very good for this crop, and should be applied liberally at the time of putting in. No dung should be applied at this time, but it is an advantage when the plants are up. Kainit is given before sowing. Superphosphate, at the rate of from 4–5 cwts., should only be applied on light soils.

Spinach.—As for cabbage.

Sprouts.—As for cabbage.

Strawberries.—Liberal manuring with dung is good for this fruit. Basic slag applied to the lower surface, and superphosphate on the surface benefit this crop. If the soil lacks dung, fish guano or rape dust may be used. If no dung is used, a potash fertiliser may be required, when

potassium sulphate should be applied in the winter. The chloride is stated to be injurious to strawberries.

Sugar beet.—There has been a rapid increase in the area cultivated for sugar beet in England and Wales, from 22,400 acres in 1924, and 54,700 in 1925, to 125,000 acres in 1926.[1] This crop appears to do best with farmyard manure, which is applied in the autumn or winter, as spring application produces fanged roots, and 12 tons per acre of dungs upplemented with complete artificial fertilisers give the best results.

After the farmyard manure in the autumn, from 3–4 cwts. of superphosphate or from 4–5 cwts. of basic slag, from ½–1 cwt. of potassium sulphate, and ½–1 cwt. of ammonium sulphate, are given. Later, to' dressings of from ½–1 cwt. of sodium nitrate are applied.

Fertiliser tests in America have shown that sodium nitrate has proved profitable when used alone or with superphosphate and potash.

Excessive quantities of nitrogenous fertilisers are to be avoided, as leaves will be produced at the expense of the roots.

Sugar cane.—Ammonium sulphate is stated to give good yields with this crop, and higher yields of cane, juice, and gur have been obtained by the application of gypsum.

Swedes.—As for turnips.

Tobacco.—The main requirement of this plant is potash. It is better to use potassium sulphate than the chloride for the manuring of this crop, as the latter causes the leaf to burn badly.

Tomatoes.—This crop responds to the application of fertilisers. Superphosphate is good for this purpose, and small quantities of sodium nitrate as a top dressing increases

[1] *Journ. of Min. of Agri.*

the yield of fruit. Excess of the nitrate diminishes the yield.

Tulips.—These plants give good results with the application of bone meal at the time of planting, and a top dressing of ammonium nitrate in the spring.

Turnips and swedes.—These crops are gross feeders, and do best with dung supplemented with artificial fertilisers rich in phosphates. They require phosphates on most soils, and if following a cereal crop, also a dressing of farmyard manure. The usual amounts to apply are from 10–15 tons of dung, and from 3–6 cwts. of superphosphate or basic slag per acre..

If " finger and toe " disease is prevalent, use no farmyard manure, which is often the source of this trouble, and the superphosphate is best replaced by bone meal or basic slag under these conditions. Cyanamide is also a useful fertiliser in these circumstances. The best treatment for the disease is the application of 10 cwts. of ground lime.

If no dung is used, a useful application consists of 1 cwt. of ammonium sulphate or $1\frac{1}{4}$ cwts. of cyanamide, or $\frac{1}{2}$ cwt. of ammonium sulphate with $\frac{1}{2}$ cwt. of sodium nitrate applied a little later, from 5–7 cwts. of superphosphate or basic slag, and 1 cwt. of potassium sulphate or chloride.

Rock phosphate, finely ground, does very well for turnips and swedes, and can replace some of the superphosphate or basic slag.

When no farmyard manure is used, and on heavy soil, it is generally necessary to increase the potash.

On light soils, fish meal can be used as a source of nitrogen and phosphate.

On peat soils, basic slag or bone compounds are better.

Wheat.—This is usually grown after potatoes in the

rotation and often does not require dung or potash. It is deep-rooted, and takes advantage of the food supplies in the soil better than a crop like barley. If it follows a heavily manured crop such as mangolds, no fertiliser is needed.

Wheat responds best to nitrogenous and phosphatic fertilisers, and if the rainfall has been excessive, in spite of the previous crop being manured, it will require fertilisers. If this is the case, from ½–1 cwt. ammonium sulphate and 3 cwts. of superphosphate should be applied.

Poor soils require phosphates in the form of basic slag, bone meal, or superphosphate.

If the plants are poor and thin, 1 cwt. of ammonium sulphate and 2 cwts. of superphosphate in the spring should be given. Phosphates hasten the ripening, and should be applied if the harvest comes late.

For spring wheat use 1 cwt. of ammonium sulphate and from 2–3 cwts. of superphosphate, unless the preceding crop has had a heavy dressing of superphosphate.

For wheat on light soils use from ¾–1½ cwts. sodium nitrate or ammonium sulphate, and 2 cwts. of superphosphate.

On heavy soils, from 2–4 cwts. of superphosphate or basic slag in the autumn, and from 1–2 cwts. of sodium nitrate or ammonium sulphate in the spring, are the usual amounts, and if the soil is in bad tilth, 30 bushels of soot will improve the condition.

CHAPTER XII

VALUATION OF FERTILISERS

In considering the value of fertilisers, it should be remembered, that, apart from their plant food value, some of them have a very real effect upon soil condition and improvement, and in the purchase of materials this point should be borne in mind. Farmyard manure especially, and then rape cake, dried blood, guano, and soot, have all an effect upon the soil and improve its physical condition.

Of primary importance, however, is their actual food value, and this is the fundamental basis of their valuation. The purely artificial fertilisers are valued according to the amounts of these constituents, and this is the first thing which determines the worth of the material.

The three plant foods considered are nitrogen, phosphate, and potash, and the various fertilisers offered are compared as to the amounts of these constituents they contain.

The Fertiliser and Feeding Stuffs Act of 1906 states "that every person who sells for use as a fertiliser of the soil any article which has been subjected to any artificial process in the United Kingdom, or which has been imported from abroad, shall give to the purchaser an invoice stating the name of the article, and what are the respective percentages (if any) of nitrogen, soluble phosphates, insoluble phosphates, and potash contained in the article."

Soluble phosphate is that soluble in water; insoluble phosphate is that insoluble in water, unless it is specified as soluble in citric acid or other solvent of prescribed strength.

These percentages must refer to these actual constituents, and not to any compound of them, such as ammonia, phosphoric acid, or salts of potash.

The unit value of a fertiliser is the cost of 1 per cent. per ton, and is obtained by dividing the price per ton by the percentage of nitrogen, soluble phosphate, insoluble phosphate, or potash, as the case may be.

EXAMPLES.—*Nitrogen.*—The cost of sodium nitrate containing 15·5 per cent. of nitrogen, was £12 10*s.* per ton in October, 1926.

Therefore the cost of 1 per cent. of nitrogen = unit value $= \frac{£12\ 10s.}{15{\cdot}5} = 16s.\ 2d.$

With ammonium sulphate containing 20·6 per cent. of nitrogen, at £11 9*s.* per ton, the unit value or cost for 1 per cent. of nitrogen $= \frac{£11\ 9s.}{20{\cdot}6} = 11s.\ 1d.$

Soluble phosphate.—Superphosphate, containing 35 per cent. of soluble phosphate, at £3 5*s.* per ton.

$$\text{Unit value} = \frac{£3\ 5s.}{35} = 1s.\ 10d.$$

Insoluble phosphate.—Basic slag, containing 30 per cent. total phosphate, at £3 6*s.* per ton.

$$\text{Unit value} = \frac{£3\ 6s.}{30} = 2s.\ 2d.$$

Ground rock phosphate, containing 58 per cent. of insoluble phosphate, at £2 10*s.* per ton.

$$\text{Unit value} = \frac{£2\ 10s.}{58} = 10d.$$

Potash.—Potash salts, containing 30 per cent. of potash, at £4 10*s.* per ton.

$$\text{Unit value} = \frac{£4\ 10s.}{30} = 3s.$$

By this method it is easy to compare fertilisers, for if, of the several forms available, one is just as suitable as another, a comparison of the price can be the deciding factor, and the one giving the lowest price per unit is the cheapest. The following are the prices per ton ruling in London during the week ending December 15, 1926.[1]

Material.	Price per ton.		Cost per unit.	
	£	s.	s.	d.
Sodium nitrate (15·5 per cent. N.) ..	13	0	16	9
Ammonium sulphate (20·6 per cent. N.) ..	11	18	11	7
Calcium cyanamide (19 per cent. N.) ..	9	10	10	0
Kainit (14 per cent. potash)	2	15	3	11
Potash salts (30 per cent. potash) ..	4	10	3	0
,, ,, (20 ,, ,,) ..	3	2	3	1
Potassium chloride (50–53·5 per cent. potash)	9	7	3	6
Potassium sulphate (48–51·25 per cent. potash)	11	5	4	5
Basic slag (30 per cent. total phosphate)	3	6	2	2
,, (24 ,, ,,)	2	11	2	1
Ground rock phosphate (58 per cent. total phosphate)	2	12	0	11
Superphosphate (35 per cent. soluble phosphate)	3	10	2	0
Superphosphate (30 per cent. soluble phosphate)	3	3	2	1
Bone meal (3·75 per cent. N. and 45 per cent. total phosphate)	8	0	—	
Steamed bone flour (0·75 per cent. N. and 60–65 per cent. total phosphate) ..	5	10	—	

[1] *Journ. of Min. of Agri.*, Jan. 1927.

The method can be used to find approximately the value of a material containing more than one of the fertilising ingredients. If a fertiliser is offered which contains 7 per cent. of nitrogen, 29 per cent. of soluble phosphate, and 3 per cent. of potash, the value can be found by working out the cost per unit of these materials and comparing them with the cost of the best forms which can be purchased.

	£	*s.*	*d.*
7 per cent. of nitrogen at 16*s.* 9*d.* ..	5	17	3
29 ,, ,, soluble phosphate at 2*s.*	2	18	0
3 ,, ,, potash at 4*s.* 5*d.* ..		13	3
	£9	8	6

Therefore the value per ton of the manure is £9 8*s.* 6*d.* compared with the best forms obtainable. To this amount must be added the cost of mixing and bagging.

In the valuation of fertilising materials, it is usually assumed that potash has the same value in all potash fertilisers, that insoluble phosphate is of less value than soluble phosphate, and that fish guano and meat meal are of higher worth than steamed bone flour.

Some price lists and literature use the terms ammonia, phosphoric acid, and salts of potash to represent the fertiliser constituents, and it might be useful to include factors for the conversion of these into the recognised terms, nitrogen, phosphate, and potash.

To convert ammonia into nitrogen	×0·824
,, ammonium sulphate into nitrogen ..	×0·212
,, phosphoric acid into calcium phosphate	×2·200
,, potassium sulphate into potash ..	×0·541
,, ,, chloride ,, ,, ..	×0·631

In the case of lime, the cost per ton delivered for each form of lime and the lime content of the material is considered.

To convert calcium carbonate into lime .. ×0·56

If lump lime is used, allowance must be made for slaking it.

The following tables give the average amounts of fertilising constituents contained in commercial materials.

NITROGENOUS FERTILISERS.

Material.	Nitrogen, per cent.
Ammonium nitrate	33–35
Ammonium chloride	25
Ammonium sulphate	20·6
Calcium cyanamide..	19
Sodium nitrate	15·5
Calcium nitrate	13
Domestic soot	2·5–11
Boiler soot	0·5–1·25
Dried blood	8–13
Urea	46
Indian rape cake	5·5 approx.
Leather	3–6
Shoddy	2·5–13
Feathers	8 approx.
Hoofs and horns	12–15
Rabbit waste	9–12
Hair	9 approx.
Sewage sludge	1–2·5
Activated sludge	6

POTASSIC FERTILISERS.

Material.	Potash, K_2O, per cent.
French kainit	14
,, extra kainit	20–22
,, potash manure salts	30 and 40
German kainit	12·5
,, potash manure salts	20 and 30
Potassium sulphate	49
,, chloride	50
Plant and wood ashes	0·5–50·0
Flue dust	3–15
Concentrated wool wash	20
Burnt spent molasses liquor	8

PHOSPHATIC FERTILISERS.

Material.	Phosphate.	
	In terms of phosphoric acid, P_2O_5, per cent.	In terms of calcium phosphate, $Ca_3P_2O_8$, per cent.
Rock phosphate	4·5–41	10–90 (insoluble)
Superphosphate	11·4–17·3	25–38 (soluble)
Double superphosphate ..	22	43 (soluble) 5 (insoluble)
Tetraphosphate	18·2	40 (insoluble)
Precipitated phosphate	up to 40	up to 88 (insoluble, but mainly soluble in citric acid)
Precipitated bone flour ..	30–40	66–88 (about half of which is soluble)
Basic slag	6·8–20	15–43 (of which 80 per cent. is soluble in 2 per cent. citric acid in the better grades, and only 20 per cent. in lowest grade).
Phosphor manganese ..	20	43 (insoluble)
Steamed bone flour ..	27·4–31·8	60–70 (insoluble)
Bone ash	33·1–34	73–75 (insoluble)
Bone black	34–36·4	75–80 (insoluble)
Spent char	30–34·5	65–76 (insoluble)

NITROGENOUS-PHOSPHATIC FERTILISERS.

Material.	Nitrogen, per cent.	Phosphate.	
		In terms of phosphoric acid, P_2O_5, per cent.	In terms of calcium phosphate, $Ca_3P_2O_8$, per cent.
Bone meal	3·5–4·5	20·5–22·7	45–50 (insoluble)
Dissolved bones	2·5–3·5	13·6–15·4	30–34 (about half soluble)
Meat meal (nitrogenous) ..	11–13	0·6–3·0	1·3–6·6 (insoluble)
„ (phosphatic) ..	6–7	14–17	31–37 (insoluble)
Fray Bentos guano ..	6	4·5–9·1	10–20 (insoluble)
German flesh guano ..	9·7	6·2	13·7 (insoluble)
Fish guano	6–10	3·6–18·2	8–40 (insoluble)
Bombay cotton cake ..	3–4·5	0·1–1·8	0·2–4 (insoluble)
Rhenania nitrogen phosphate	9·8	3·4	7·5 (citrate soluble)
Diammonphos	19	47	103·4 (readily available)
Leunaphos	20	15	33 (readily available)

NITROGENOUS-POTASSIC FERTILISERS.

Material.	Nitrogen per cent.	Potash per cent.
Potassium nitrate (Indian crude) ..	3–10	11·5–35
,, ,, (technical) ..	13	45
Seaweed (wet)	0·23–0·38	0·8–1·8
,, (dry)	1·3–1·5	2·5–10·5
Kelp ash	—	12–25
Raw wool	5–8	0·5–3
Tobacco stems	1·7–2·5	7–8
,, dust	2·5–3·3	2–3

NITROGENOUS-PHOSPHATIC-POTASSIC FERTILISERS.

Material.	Nitrogen, per cent.	Phosphate. In terms of phosphoric acid, P_2O_5, per cent.	Phosphate. In terms of calcium phosphate, $Ca_3P_2O_8$, per cent.	Potash, K_2O, per cent.
Farmyard manure ..	0·45–0·65	0·2–0·4	0·44–0·88	0·4–0·8
Poultry manure ..	1·9	1·0	2·2	0·55
,, ,, (dry)	5·2	2·5	5·5	1·4
Pigeon dung	1·2–2·4	1·7–4	3·7–8·8	1·1–2
Duck's dung	0·8–1	1·4–3·5	3·1–7·7	0·6–0·8
Geese dung	0·6	0·5–0·9	1·1–2	1·0–1·2
Bat guano (variable)	8	3·8	8·4	1·3
Guanos (very variable)	2–11	6·8–18·2	15–40	1–4
Castor meal	4–7	1·5–3·5	3·3–7·3	1·9–2·5
Cotton seed meal ..	7–10	1–3	2·2–6·6	1·5–3
Linseed meal ..	3·5–5·5	1·2	2·2–4·4	1–2
Tung oil cake ..	3·2–3·5	0·8–1·2	1·8–2·6	0·8–1·1
Night soil	5	5	11	2·5
Town refuse (Ashpit)	0·4–1·21	0·2–1·15	0·44–2·53	0·3–0·64
Sugar cane waste ..	1	4·2	9·2	3·3
Brewers' grains and Spent hops (wet)	0·62	0·42	0·92	0·05
Ditto (dry) .	2·5	1·6	3·5	0·2
Tapioca refuse ..	0·61	0·56	1·2	0·58
Cocoa shells	2·5	0·75	1·6	2·5
Leunaphoska.. ..	13	10	22	13
Nitrophoska I. ..	17	11·7	25·7	21
,, II. ..	14·7	10·2	22·4	26·6

The choice of a particular fertiliser will depend upon circumstances and conditions.

The cost per unit of the material is of primary importance, but other considerations must influence the user.

The condition of the fertiliser in regard to its fineness of division and suitability for distribution, whether it will deteriorate on storing, or become unsuitable, and require breaking up before use, are all of importance in the economy in the use of fertilising materials.

The suitability of a manure for a particular soil must be studied, for some soils require organic matter and will give better results with an organic fertiliser. Some plant foods have a quicker effect than others.

The costs of mixing, cartage, and distribution are also important items which influence the choice of fertilising materials.

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